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EXHIBIT

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PHASE I REPORT
FOR OIL POLLUTION ABATEMENT
AT RADNOR YARD
OF CSX TRANSPORTATION, INC.

MAY 1991

RCI PROJECT NO. 8-3553.05

Prepared for:

CSX TRANSPORTATION, INC.
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RESOURCE CONSULTANTS

TABLE OF CONTENTS

Page No.

Page No.

Page No.

APPENDICES

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

CSX Transportation, Inc. (CSXT) entered into an Agreed Order with the Tennessee Water Quality Control Board in May, 1990, to investigate and abate releases of petroleum hydrocarbons from the Radnor Yard site in Nashville, Tennessee. This agreement included the preparation and submittal of a Corrective Action Plan (CAP), submitted in July, 1990, which outlined proposed actions to address the following items:

a. possible interim remedial measures;

b. an investigation and mapping of existing subsurface storm water and wastewater drainage systems;

c. an investigation to establish the areal and vertical extent of soil and/or groundwater contamination;

d. development of final remedial measures based on the findings of the above investigations;

e. implement such remedial measures; and

f. perform monitoring of discharges and the receiving waters pending implementation of all selected remedial design and remedial action measures.

This report presents the findings of these investigations and outlines a phased approach for implementing remedial actions. Some of the design work for achieving improvements at Radnor Yard have already been initiated. A brief summary of the findings of the investigations at Radnor Yard is presented below.

The storm, sanitary and the industrial (free-oil and emulsified-oil) sewers at the plant site have been mapped and connections confirmed using smoke and dye testing methods. Some additional confirmation work is still required in the area around the roundhouse. The storm sewer system for this site is complex, with storm water from the major portion of the site (the central and western parts) draining into the storm water retention basin located on the western side of the site. A substantial amount of the precipitation falling onto the site is thought to drain through the ballast and subsurface fill materials, and generally follow the surface of the former valley floor beneath the site.

In addition to the mapping program, the older segment of the roundhouse storm sewer was entered and physically inspected to the extent possible. The primary purpose of this work was to assess the condition of this sewer and determine whether televising of the entire length between the manhole near the wastewater treatment facilities and the oil recovery manhole was feasible.

The inspection revealed that a number of joint displacements have occurred along the portion of the pipe inspected, and that persistent infiltration was occurring, even during dry summer periods. The samples of infiltrating flow collected did not exhibit elevated TRPH concentrations, in contrast to the samples collected from the bottom of the sewer pipe and at the oil recovery manhole. A water leak in the water supply system was subsequently discovered near the sewer alignment and repaired. Based on observations since this work was completed, however, the storm sewer still carries a moderate dry-weather flow with significant associated TRPH levels. This may be due to other water line leaks, subsurface infiltration, or possible connections of unknown drain lines (such as foundation drains, french drains, etc.).

A complete inspection of the roundhouse storm sewer was not possible due to limitations in the length of air-supply line to the investigators. A swag in the sewer line about 30 feet to the east of the oil-recovery manhole prevented further progress from this entry point. This dip in the pipe was partially submerged and did not provide sufficient head space to allow the investigator to advance further. A future camera survey of the portions of the sewer not inspected is not considered feasible due to the dip and depth of standing water observed in the sewer. The feasibility and cost of constructing a manhole at the intersection of the roundhouse storm sewer and the 2 x 2 box culvert are being evaluated. Provision of an additional sewer entry point at, or near, this location, would enable access to almost all of the uninspected segments of these sewers.

A geologic/hydrogeologic subsurface investigation was performed to ascertain the nature of the site geology, hydrogeology and examine the vertical and horizontal extent of subsurface petroleum hydrocarbon contamination at the site. The investigation included the drilling of 20 boreholes and installation of 6 piezometers. Briefly, the majority of the property is a former valley which has been extensively modified and levelled using clay and boulder fill material. The depth of fill material varies from 0 to 50 feet deep. Cinders were found in the area of the roundhouse. A layer of natural silt lies between the fill and limestone bedrock, and acts as a confining layer for the groundwater in the limestone bedrock. Perched groundwater exists on the eastern side of the site but the drainage path of the perched groundwater could not be accurately determined with the information gathered during the Phase I investigation.

Analyses of soil and perched groundwater samples collected around the roundhouse and wastewater treatment areas showed elevated total recoverable petroleum hydrocarbon (TRPH) levels. The more heavily contaminated areas included the area south of the locomotive shop, the diesel fuel storage tank and the former lube oil storage tank area. Analyses for specific organic pollutant compounds showed the contamination at the first two locations was associated with either diesel fuel or coal-tar derivative compounds. In addition, soil and perched groundwater analyses from samples collected from the two boreholes on the eastern edge of the site (BH-3 and BH-6) revealed low concentrations of volatile compounds. These compounds are not typically associated with railway operations.

While sample analyses showed that the perched groundwater had been impacted, no degradation of the limestone aquifer was observed at any of the boreholes. Some phthalates were detected in the priority pollutant scans but these occurrences were attributed to the use of PVC screens and risers. Chloroform and methylene chloride were also detected at background levels but were suspected laboratory contaminants.

Heavy surface contamination of ballast due to oil leakage from the locomotives in the area of the roundhouse was investigated as a potential source. Excavations of the ballast showed that oil migration typically did not extend beyond one foot below the surface. More extensive migration was observed at several areas next to damaged track pans. While these locations provide several potential contaminant sources which need to be eliminated, no single spot has been targeted as representing a major source of subsurface contamination.

While the subsurface investigation revealed several significantly contaminated subsurface areas, a direct link between these areas and the petroleum hydrocarbon compounds that are being routed via the roundhouse storm sewer to Browns Creek was not established. In fact, the opportunity for the petroleum compounds to find their way into the storm sewer from subsurface soils seems limited due to the characteristics of the petroleum compounds to remain at water surface levels and to absorb onto soil particles. The drainage path of the perched groundwater and the ability of the petroleum products to move through the fill material requires further investigation.

Observations of the performance of the oil-recovery manhole and a review of this unit and the entire free-oil wastewater treatment system revealed the need for improved effectiveness and better efficiencies.. The ability of the oil-recovery manhole to effectively separate petroleum products during storm flows deteriorates due to turbulence in the sewer caused primarily by road drainage and the entry of the car shop area run-off via a vertical drop just upstream of the manhole. Soils with absorbed petroleum hydrocarbons tend to accumulate in the bottom of the manhole and during turbulent flow pass under the baffle. In addition, plant operators find it necessary to stop pumping the return flow from the oil recovery manhole to the free-oil system during storm events because of the flow limitations in the surge lagoon. This situation allows a significant amount of the petroleum hydrocarbons to bypass the baffle in the oil-recovery system and enter Browns Creek.

The proposed remedial actions concentrate initially on correcting the defined problems at the oil-recovery manhole. Initially, this structure will be modified or replaced to eliminate the sources of turbulence which are mixing the petroleum hydrocarbons and water. A more efficient method of separating the petroleum hydrocarbons will also be sought, and the structure will be modified to divert flow for additional treatment. The second phase consists of providing additional treatment capacity at the site. The correction of the manhole design and additional treatment capacity at this location should result in a substantial improvement in the quality of water discharged via the roundhouse sewer line. Following implementation of these two phases, the water quality in Browns Creek will be monitored. If significant TRPH concentrations are still present, the feasibility of a permanent skimming structure (or other facilities) at, or near, the existing discharge point will be evaluated and constructed if necessary.

1.0 INTRODUCTION

1.1 BACKGROUND

CSX Transportation, Inc. (CSXT) has entered into an Agreed Final Order with the Tennessee Water Quality Control Board to investigate and abate releases of petroleum hydrocarbons in storm waters originating from the Radnor Yard site located in Nashville, Tennessee. In July, 1990, Resource Consultants, Inc. (RCI), with the assistance of their geotechnical subcontractor, Golder Associates, Inc. (Golder), prepared and submitted a Corrective Action Plan (CAP) to the Tennessee Division of Water Quality. The CAP outlined an investigative program for the site, and included descriptions of:

- the site and site history,
- regional geologic and hydrogeologic characteristics,
- the operations that are presently conducted at the yard,
- potential sources of petroleum hydrocarbons,
- potential pathways for petroleum hydrocarbon migration,
- interim control measures to minimize hydrocarbon releases,
- a proposed investigation of site drainage systems,
- a proposed investigation on the extent of site contamination, and

- a proposed interim monitoring program of surface and groundwaters at the site.

From the information gathered in the above program, alternatives for final remedial measures are to be developed to reduce the amount of petroleum hydrocarbon discharges to acceptable levels.

This document reports the findings of the above studies available to date, and presents the final remedial solutions that are being reviewed. Some additional data is still needed. The scope of the additional work to obtain this data is described and will be conducted simultaneously to the detailed design of the final selected remedial measures.

1.2 OBJECTIVES AND SCOPE

The objectives of this report are to provide a detailed summary of the work conducted to date at the Radnor Yard, and to discuss the significance of the information gained with regard to the final remedial options for this site.

1.3 REPORT ORGANIZATION

This report has been prepared as follows. Chapter 2, entitled "Site Characterization", provides the reader with a description of the site, including a brief description of the main site features and history, and a description of the regional setting. This pertains particularly to the geological and hydrogeological characteristics of the south Nashville area. Chapter 3 presents descriptions of the methodologies used for the various investigations that were included in this project. Chapter 4 presents the results of these investigations. Chapter 5 includes a summary of the contamination sources contributing to the TRPH releases into Browns Creek, and the suspected migration pathways. A description of the remedial alternatives being evaluated is also included. Finally, Chapter 6 outlines the areas where additional investigations are considered necessary.

2.0 SITE CHARACTERIZATION

2.1 SITE DESCRIPTION AND HISTORY

The CSXT Radnor Yard covers several hundred acres in south Nashville, Davidson County. A site location map is presented in Figure 1. The Yard is bordered by Harding Place to the south, Trousdale to the east, Veritas and its extension to the north and Sidco Drive defines the western border. The facility is roughly split in half by the hump yard and classification tracks. Access to the site is available from the east by using the extension of Veritas Street, from the west by entering off of Sidco Drive on the south near the old Mayton Tower/Hump Yard Tower access road and from the north by a TOFC/COFC access road.

The original terrain upon which the Radnor Yard complex was constructed is the upland hill-and-valley watershed of the East Fork of Brown's Creek. Figure 1 also shows local topography surrounding the site. Figure 2 is a detailed topographic map of the site. The eastern and southern edges of the property lie along a low ridgeline which form the eastern and southern edges of the East Fork of Brown's Creek watershed. The East Fork of Brown's Creek is an intermittent stream which forms from wet-weather springs and storm water runoff across the site. Flow into the East Fork of Brown's Creek and the wet-weather springs feeding the creek is highly rainfall dependent. Beginning early in the century and continuing through the years, the site has undergone several terrain alterations as the Louisville and Nashville (L&N) Railroad, and its successor railroads, constructed, modernized and expanded the Radnor Yard facility. Today the feeder branches of the East Fork of Brown's Creek flow through a deep underground culvert under the western side of the CSXT property and surface approximately 250 yards to the northwest of the site.

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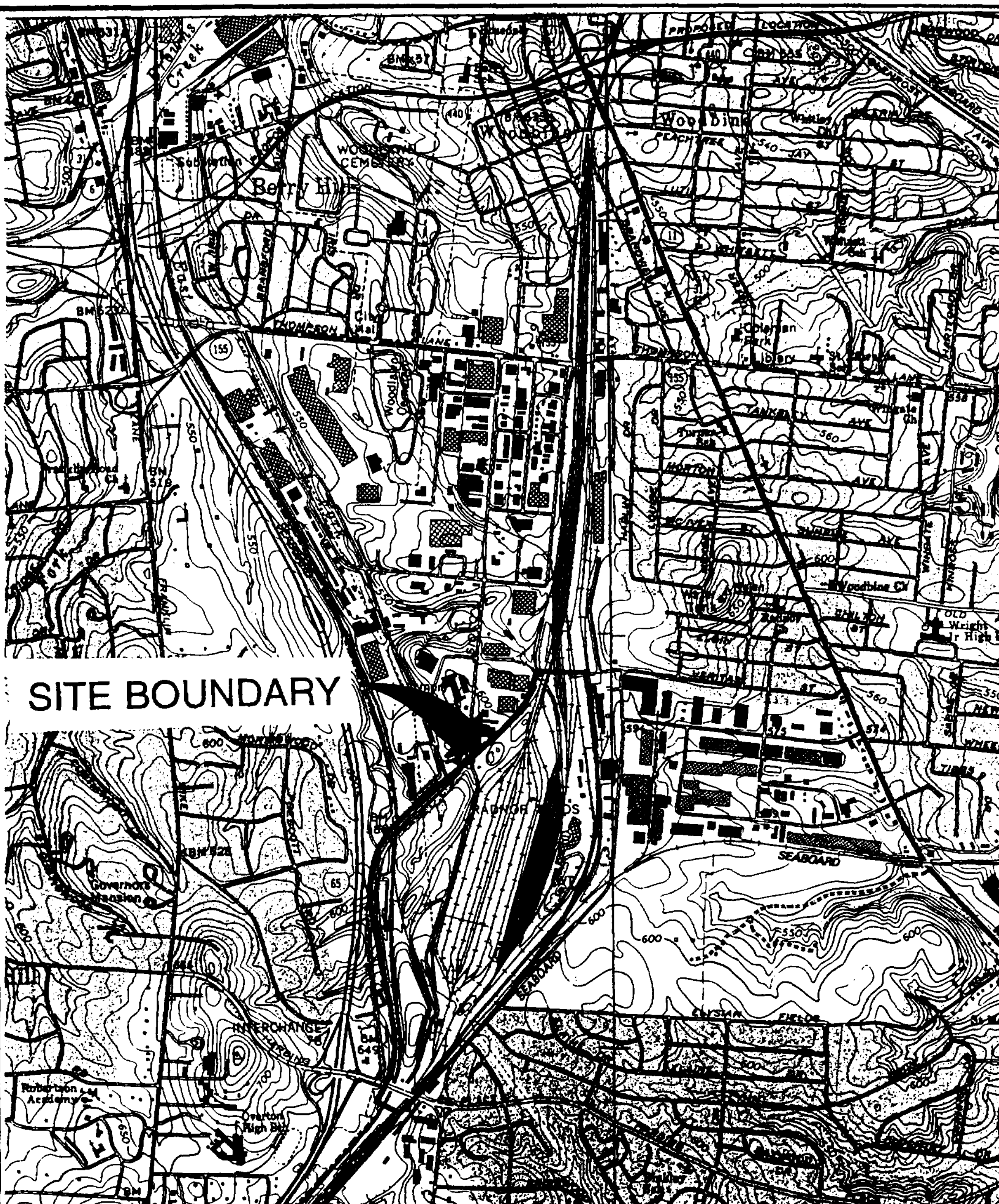

REFERENCE: U.S.G.S. ANTIOCH AND OAK HILL SCALE 1"=2000'

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FIGURE 1

SITE LOCATION MAP
CSXT RADNOR YARD
NASHVILLE, TENNESSEE

OVERSIZED

DOCUMENT

(1)

Construction of the first shops and yards was begun by L&N in the building of the Lewisburg and Northern Railroad between 1910 and 1918. The early structures consisted of a roundhouse, turntable, and water and coaling facilities for steam locomotives. The yards which were constructed included classification, receiving and advance tracks which were north, east and west of the roundhouse, respectively. The steam locomotives required coal as fuel, large quantities of water for the production of steam, sand for traction and various oils and greases. A large coaling tower and coal storage stockpile was located northwest of the roundhouse. Water was supplied from Radnor Lake, several miles from the southwest by a pipeline, to watering facilities west of the roundhouse.

L&N gradually changed from steam to diesel powered locomotives between 1950 and 1957. Significant quantities of fuel oil were not stored at Radnor Yard until the switch from steam to diesel had occurred. In 1953, a 259,000 gallon diesel storage tank was erected west of the roundhouse, with fueling operations taking place on aprons west and north of this tank. Modernization and expansion of the servicing area resulted in the abandonment and removal of this early diesel fuel storage and fueling facility. A new diesel servicing facility was constructed, south of the roundhouse, in the late 1950's along with a diesel locomotive repair house and a 500,000 gallon diesel fuel storage tank. This diesel storage tank was located in a low area, south-southeast of the roundhouse. Also located in that area, at the head of the main storm drain which flowed westward to the East Fork of Brown's Creek, was an oil skimming pond.

The middle 1950's also saw the construction of the classification yard at Radnor. Construction of the new yard required a major amount of cut and fill south and west of the roundhouse complex. Large diameter culverts for conveying storm water runoff were extended several thousand feet to the west, toward the East Fork of Brown's Creek. The culverts were laid in the drainage ditches which once carried storm water to the East Fork of Brown's Creek.

In the early 1970's the railroad constructed a pollution control plant, consisting of physical and chemical processes to reduce oily water discharges into the East Fork of Brown's Creek. In 1977, a spill prevention lagoon was constructed on the west side of the yards. The lagoon was in the low-laying area adjacent to the East Fork of Brown's Creek, just upstream from where the East Fork entered a culvert and passed beneath Sidco Drive. The lagoon served as a gravity oil/water separator and contained an oil skimmer to remove the floating oil and a pump for transferring the oil for recovery or disposal.

Although the problem of oily water in the creek abated somewhat over the ensuing years, it became apparent that a major expansion and modernization of the original pollution control facilities would be necessary. In the early 1980's the L&N Railroad undertook a multi-million dollar project to completely rebuild the oily wastewater pollution control system at Radnor Yard.

The new water pollution control facilities included industrial sewers which segregated wastewaters containing emulsified oils from wastewaters containing free oils. An industrial sewer was installed to convey oily wastewaters to a series of lagoons, southeast of the roundhouse area. These lined lagoons contain baffled chambers and oil skimmers which remove the floating free oils and transfer it to oil recovery sumps. The free oils are then pumped through underground lines to aboveground oil storage tanks. The effluent remaining after oil removal travels to a lift station, where it is pumped into the Metropolitan Nashville sanitary sewer.

An industrial sewer also collects and transports emulsified oily wastewater to a physical-chemical treatment system specifically designed for emulsified oily waste. The emulsified oil wastewater treatment system consists of chemical feed pumps, mixers, mixing chambers, and a dissolved air flotation system which floats the oils when the emulsion is chemically broken. After the oil is separated from the water, the remaining effluent is transported to the treated effluent pump station where it is also pumped to the Metropolitan Nashville sanitary sewer. This wastewater treatment facility was constructed in the low area south and east of the roundhouse.

The spill prevention lagoon served as a significant oil recovery facility during the time when the new oil collection and treatment facilities were being installed. However, after completion of the new pollution facilities in 1983, the lagoon was removed in order to construct the trailer-on-flat-car (TOFC) and container-on-flat-car (COFC) piggyback yard. At that time, a baffled manhole and recycling lift station was constructed west of the car shops and east of the tracks of the classification yard to recover oils which were still escaping down the main storm sewer into the East Fork of Brown's Creek, .

The new TOFC/COFC facility completely changed the topography of the valley of the East Fork of Brown's Creek within the CSXT property boundaries. The entire valley was filled and the East Fork of the creek was placed in a concrete culvert. Storm drains originating on the eastern side of the property were continued in lines along the valley floor and collected storm water joins the East Fork of Brown's Creek at a depth of 50 feet, near a manhole. This combined flow is piped through the area where the spill lagoon was previously located to a culvert. The culvert transports the storm water runoff as well as the intermittent flow of the East Fork of Brown's Creek beneath Sidco Drive, on the northwest side of the yard. The culvert empties into the open channel of the East Fork, about 250 yards downstream.

2.2 REGIONAL SETTING

2.2.1 General

The geology and hydrogeology of the site can be fully appreciated only when the site's relationship to the regional physical setting is understood. In the following sections the climate, geology, hydrology, and hydrogeology of the Nashville area are presented.

2.2.2 Climate

North-central Tennessee has a climate which ranges from mild to temperate. The average mean annual temperature in Nashville is 59.1° F. The annual range between monthly mean minimum and monthly mean maximum temperature is about 52°, from 37.1° in January to 89.8° in July. The lowest recorded temperature is -17° while the highest recorded temperature is 107°. Nashville averages about 210 frost-free days per year.

Normal annual rainfall for Nashville is 48.4 inches, with the wettest month being March (5.5 inches) and the driest month being October (2.5 inches). The maximum recorded 24-hour rainfall is 6.6 inches. Thunderstorms occur on about 54 days each year, and most occur during late spring and summer.

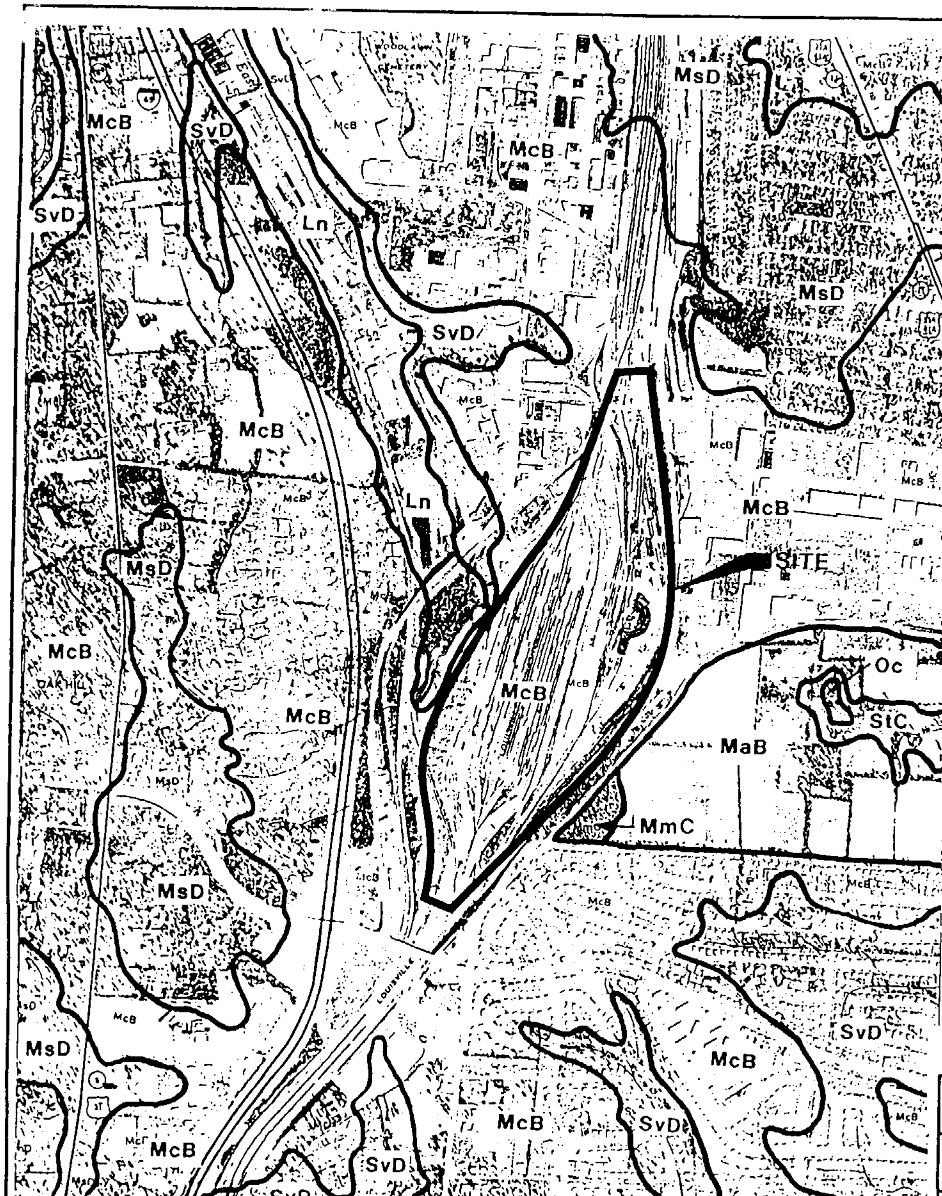
The average relative humidity in the afternoon is 58 percent. Humidity is higher at night, and the average in the morning is 79 percent. The skies are clear or partly cloudy 208 days out of the year, on average. The prevailing wind direction is from the south, averaging eight miles per hour, and is highest, averaging 10 miles per hour, in March.

2.2.3 Soils

The soil in the region is mostly residual in situ regolith (weathered rock debris) or alluvial material deposited by tributary streams of the Cumberland River. The soils in the site area, as presented in the Soil Conservation Service's 1981 Soil Survey of Davidson County, Tennessee, are shown on Figure 3. The figure does not reflect recent changes to the ground surface such as placement of fill at the Radnor Yard. The natural soil thickness averages 55 to 65 inches, beneath which limestone bedrock occurs. The soils are slightly acidic and include silt loam and silty clay loam at the surface, and friable silty clay to firm clay deeper in the soil profile.

2.2.4 Geology

The Radnor Yard is located in the southern part of the Inner Blue Grass physiographic region that stretches from central Kentucky through north-central Tennessee (Figure 4). This broad region is partly underlain by biogenic (organism-produced) limestones and calcareous (calcium carbonate) shales of Middle Ordovician age (approximately 470 million years ago). In Tennessee, these strata occur within a broadly elliptical inlier called the Central (Nashville) Basin. The Radnor Yard is located within this basin. Most of the basin lies between the elevations of 500 and 700 feet above mean sea level (ft-MSL), in contrast to the surrounding Inner Blue Grass that is consistently 200 to 400 feet higher. The basin is surrounded by the Highland Rim escarpment. The strata within the inlier are brought to the surface in limited exposures by the Nashville dome. The Nashville dome is a broad anticlinal structure that forms the southern part of the Cincinnati arch, which occupies all of central Tennessee. The arch forms the backbone for the Blue Grass physiographic region.



SOIL LEGEND

SYMBOL	NAME
McB	MAURY-URBAN LAND COMPLEX, 2% to 7% SLOPES
MsD	MIMOSA-URBAN LAND COMPLEX, 5% to 25% SLOPES
MaB	MAURY SILT-LOAM, 2% to 7% SLOPES
Oc	OCANA CHERTY SILT LOAM
StC	STIVERSVILLE LOAM, 3% to 12 % SLOPES
SvD	STIVERSVILLE-URBAN LAND COMPLEX
Ln	LINDELL-URBAN LAND COMPLEX
Mmc	FROM MAURY SERIES

NOTE: EXTENSIVE AREAS OF CUT AND FILL HAVE MODIFIED ACTUAL EXISTING SITE SOIL TYPES AND DISTRIBUTION.

SCALE IN FEET

0 1000 2000

REFERENCE: SOIL SURVEY OF DAVIDSON COUNTY, TENNESSEE BY UNITES STATES DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE, DATED 02/81.

Golder Associates
Atlanta, Georgia

TITLE: SURFACE SOILS

CLIENT/PROJECT: RESOURCE CONSULTANTS

DATE	SCALE	JOB NO
2/18/91	AS SHOWN	903-3174

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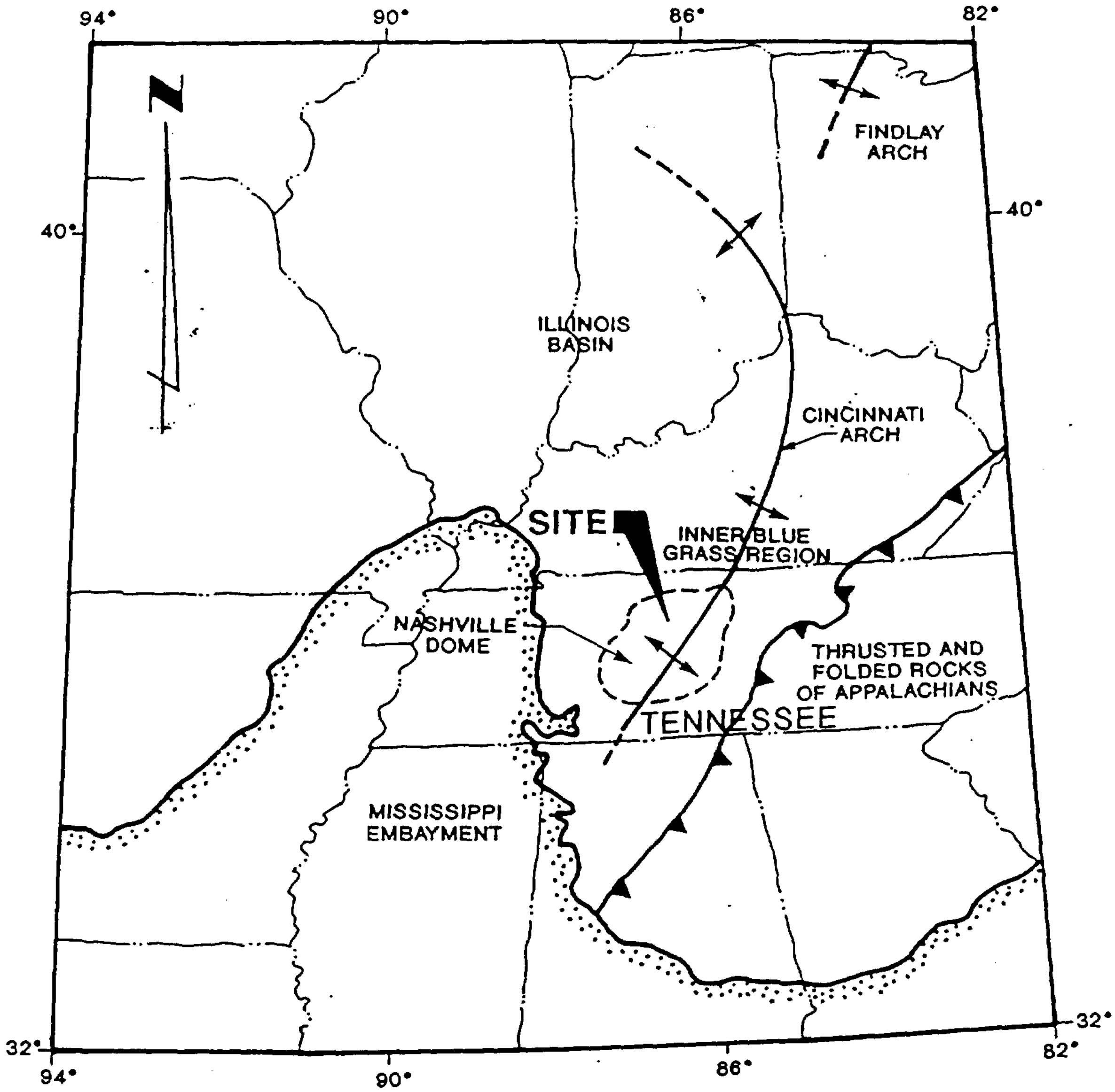

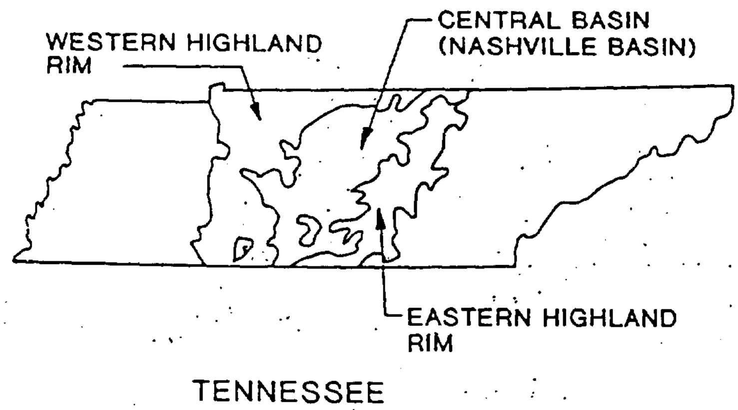

LEGEND

REGIONAL ANTICLINE

THRUST FAULT

Golder Associates, Atlanta, Georgia	TITLE: REGIONAL PHYSIOGRAPHY		
CLIENT/PROJECT: RESOURCE CONSULTANTS	DATE 2/18/91	SCALE N.T.S.	JOB NO. 903-3174
DRAWN GEH / CHECKED / REVIEWED	FILE NO. 903-3174	DWG. NO. / REV. NO. 6	FIGURE 4

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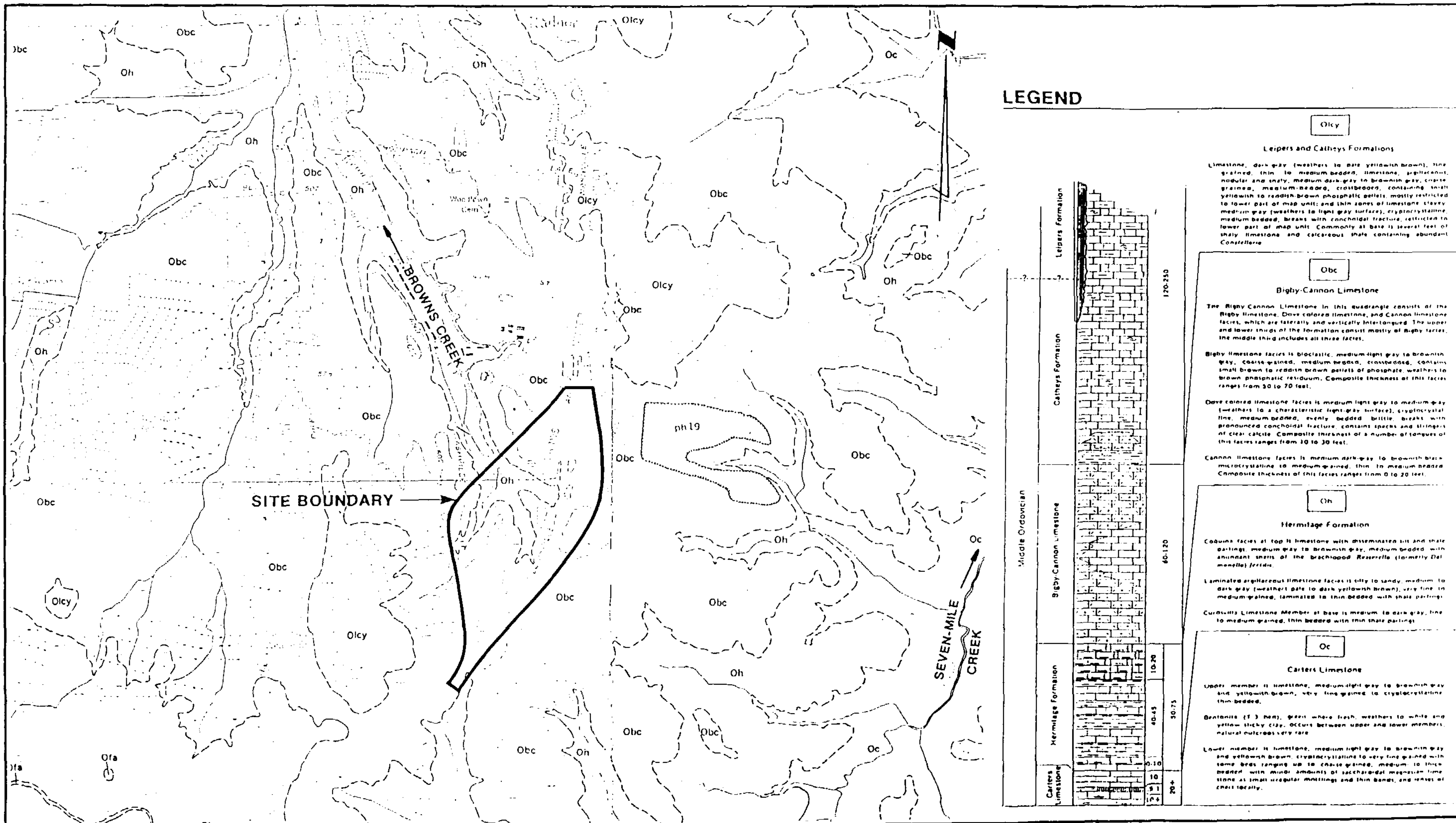
The youngest strata occupy the bluff slopes on isolated knobs of the Highland Rim escarpment. Successively older formations occupy the lowlands and valley walls of the entrenched drainage systems feeding into the Cumberland River. The bedrock in the site area is comprised of a sequence of late Middle to Upper Ordovician age carbonates and calcareous shales. These units belong, from oldest to youngest, to the Carters, Hermitage, and Bigby-Cannon Formations of Middle Ordovician age, and the Leipers and Catheys Formations of Middle to Upper Ordovician age (Figure 5). This package is underlain by the Lower Ordovician age Richmond Group, and overlain, on the Highland Rim, by a Devonian to Mississippian age (approximately 400 to 320 million years ago) package of clastics, consisting of the Chattanooga Shale, and siltstones, shales and mudstones of the Mississippian age Fort Payne Formation.

The oldest outcropping formation in the area of the site is the Carters Limestone. Upper members of the formation are present in the valley floors and valley bluffs along Sevenmile Creek, located one and one-half miles to the east of the site. The Carters Limestone is a fine- to coarse-grained, medium- to thick-bedded, saccaroidal (granular texture) limestone with characteristic chert lenses, and cherty limestone interbeds.

Overlying the Carters Limestone is the Hermitage Formation. It consists of bioclastic (composed of organism fragments) and coquina (composed of shell fragments) limestone, with characteristic disseminated silt and shale-partings, and interbeds of argillaceous (clay-containing), non-fossiliferous, calcareous limestone. Laminated to thinly-bedded, argillaceous, medium-grained, sandy limestones occur throughout the formation. The Hermitage Formation underlies a large part of the area, and occurs within the Browns Creek streambed and as ledge formers along Sevenmile Creek. Stream gradients on tributaries to Sevenmile Creek noticeably increase as the Hermitage Formation is approached.



REFERENCE: WILSON, 1964, AND WILSON AND MILLER, 1972

Golder Associates, Atlanta, Georgia	TITLE: REGIONAL GEOLOGY & SURFACE WATER DRAINAGE		
CLIENT/PROJECT: RESOURCE CONSULTANTS	DATE: 2/18/91	SCALE: AS SHOWN	JOB NO: 903-3174
DRAWN: GEH / CHECKED: / REVIEWED:	FILE NO: 903-3174	DWG NO / REV NO: 3	FIGURE: 5

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The Hermitage Formation is overlain by the purer, but coarser grained, fossiliferous limestones of the Bigby-Cannon Formation. These limestones are typically bioclastic, cross-bedded, medium to thick bedded, and microcrystalline to muddy. Phosphatic, sandy to silty layers occur throughout the formation.

The Leipers and Catheys Formations occur as topographically higher bluff formers away from the Radnor Yard site. This package of rocks consists of fine-grained, thin- to medium-bedded, argillaceous, nodular, shaly to sandy, fossiliferous limestones. Basal beds are highly fossiliferous and shaly in character.

Faulting in the Nashville dome is not common, but small normal faults do occur (Wilson, 1948 and 1949). These structures are generally steeply dipping (60 to 80 degrees) and stratigraphic throws range from 92 meters (300 feet) to more common displacements of about 15 meters (50 feet). Many of these faults are so poorly exposed that rarely can they be followed over a ground distance of several kilometers.

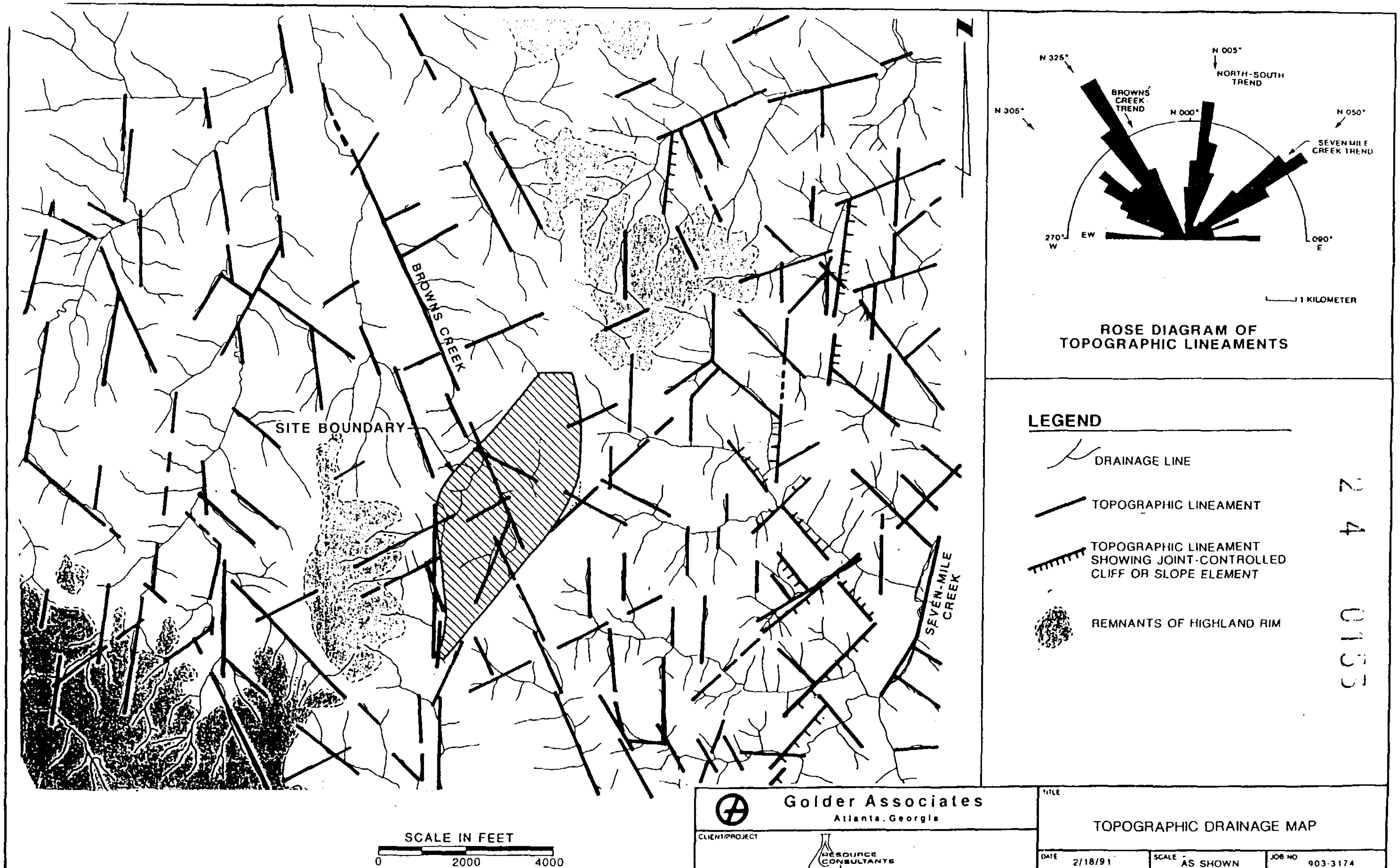
The strata in the Nashville dome are fractured by regionally pervasive joint sets. Joint concentrations increase as secondary flexures that occur on the flanks of the dome are approached. Joint intensity, as measured by their spacing, increases with the decrease in bedding thickness (as in the platy, argillaceous and thinly bedded limestones). Through-going and persistent joints that form part of regional sets are generally well spaced, and best developed in the more thickly or massively bedded carbonates. The joint pattern in most of the northern flank of the Nashville dome is fairly consistent and mostly vertical. The sets forming this pattern trend approximately N295° to N305° and N035° to N045° (Piper, 1932; Newcome, 1958). In the Nashville area (Nashville West Quadrangle), however, the joints occur in two sets, N350° to N030°, and N295° to N080° (Wilson, 1948). This wider azimuthal spread suggests that the valley entrenchment by the Cumberland River (approximately 4.5 miles north of the site) has superposed stress-release joint sets on the regional joints. Stress-release joints generally tend to run parallel with the trend of the entrenched valley wall. Because the Radnor Yard is 4.5 miles from the river, stress-release joints have not been observed on and near the site.

The lowlands developed on the limestones in the central part of the basin, where the site is located, consist of a moderate karst plain, with local areas of bedrock exposed in flat pavements called "glades". Karst topography is developed by groundwater dissolution of the underlying carbonate bedrock. The majority of the surface karst features occur as sinkholes over solutional openings through the relatively thin soil regolith. Caves and solutionally-enlarged joints are often present beneath the ground surface.

2.2.5 Hydrology

The surface waters of the region drain into the Cumberland River which empties into the Mississippi River. In the area of the site, surface water drains northward into the Cumberland River by way of its tributaries, Browns Creek, to the west of the site, and Sevenmile Creek, to the east of the site.

In an area underlain by jointed bedrock, the regional structure and fracture pattern can control the development of drainage patterns and also the topography. This may well be the case where tributary streams seem to have a preferred compass orientation at consistent angles to a main structural trend. The effect of pervasive jointing appears to be expressed in structural control of drainage patterns in the area (Figure 6). Large segments of stream courses are rectilinear, resulting in angulate drainage patterns.



Golder Associates
Atlanta, Georgia

CLIENT/PROJECT: RESOURCE CONSULTANTS

TITLE: TOPOGRAPHIC DRAINAGE MAP

DATE 2/18/91	SCALE AS SHOWN	JOB NO 903-3174	
FILE NO 903-3174	DWG NO / REV NO 1	FIGURE 6	
DRAWN GEH	CHECKED	REVIEWED	

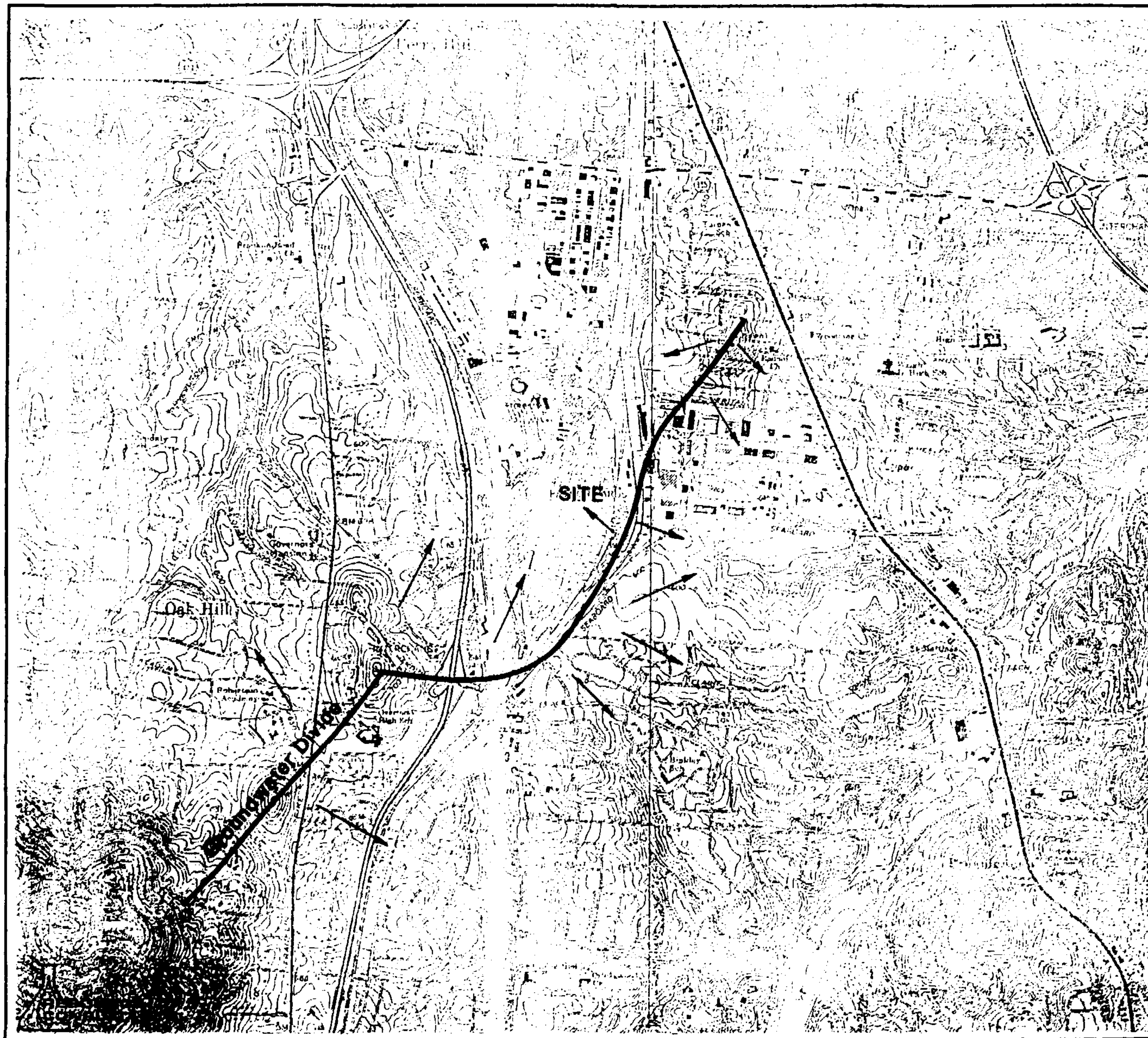
A rectified drainage pattern analysis was conducted to ascertain the effect of possible structural control. A rose diagram constructed for the azimuthal spread of rectilinear stream courses (see insert, Figure 6) yields a pattern that is remarkably similar to the regional joint pattern discussed in Section 2.2.4. The principal trends observed are N005°, N050°, East-West, N305°, and N325°. Length-weighted linear segments of streams were counted to accentuate the N325° and N050° trends that are parallel with Browns Creek and Sevenmile Creek, respectively. These alignments are similar to regionally pervasive joint trends observed along the western flanks of the Nashville dome. The trends observed in the rose diagram are also similar to the joint patterns observed during geologic mapping at the Radnor Yard (Section 4.3). Browns Creek and the headwaters of Sevenmile Creek are excellent examples of such rectilinear stream courses.

2.2.6 Hydrogeology

A literature search has shown that very little is published about the hydrogeology and karst features of Davidson County. A few caves and springs have been reported in the Nashville area, but little geologic detail can be gleaned from published reports. A literature base does exist on karst elsewhere in the region which clearly shows that caves and other groundwater flow conduits in carbonate rocks are solutionally enlarged secondary permeability features. For example, the karst topography and hydrogeology of the northern flanks of the Nashville dome have been well studied in Montgomery County, approximately 35 miles northeast of the site area. Sinkholes and cave passages in Montgomery County have been shown to be strongly structurally controlled by N020° to N040° and N330° to N350° trending joint sets. Similar trending joint sets have been mapped in the site area and it is likely that the karst in the site area is also controlled by solutioned fracture permeability.

Some speculations about local hydrogeology can be made based upon topography and hydrology. The broad topographic flat on which the site is located marks the drainage divide between Browns Creek to the west of the site and Sevenmile Creek to the east (Figure 7). The elevation of this topographic flat is about 620 ft-MSL near the site, but elevations of over 1000 ft-MSL exist to the southwest of the site. Browns Creek and Sevenmile Creek occupy valleys at an elevation of about 520 ft-MSL. The ground distance from the site to the main valleys of Browns Creek and Sevenmile Creek is about one and one half miles. Head waters of each creek, such as the East Fork of Browns Creek, display an upstream steepening in profile at about 550 ft-MSL, about the elevation where a majority of the springs draining the uplands are expected, since the headwater valleys broaden below this elevation. The U.S. Geological Survey Water Resources Bulletin of North Central Tennessee reports that the majority of springs draining the karst lowlands in the Nashville area occur in the Hermitage Formation. The upper contact of the Hermitage Formation with the overlying Bigby-Cannon Formation occurs at about 530 ft-MSL along the bluffs bounding Sevenmile Creek and in the vicinity of Browns Creek.

Based on the above information, it is suggested that groundwater drains from the elevated uplands southwest of the site to the northwest, north and northeast, through fracture controlled systems, emerging as springs at or very close to the Hermitage and Bigby-Cannon formational contact in the two creek valleys (Figure 7).



LEGEND

ELEVATION GREATER THAN 750 ft-MSL

ELEVATION 700-750 ft-MSL

ELEVATION 650-700 ft-MSL

ELEVATION 600-650 ft-MSL

ELEVATION 550-600 ft-MSL

ELEVATION LESS THAN 550 ft-MSL

GROUNDWATER FLOW DRIECTION

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SCALE 1" = 2000 ft

FIGURE 7

CONCEPTUAL REGIONAL GROUNDWATER MAP

CSX RADNOR YARD
NASHVILLE, TN
RCI # 8-3583.02

3.0 PHASE I INVESTIGATION METHODOLOGIES

3.1 INTERIM MONITORING PROGRAM

As a part of the Corrective Action Plan, CSXT Transportation, Inc., has performed an interim sampling program to monitor the impact of the storm sewer discharge on the East Fork of Browns Creek. Samples were collected on a monthly basis between July and November of 1990. The monitoring program consisted of collecting and analyzing surface water samples from five locations and groundwater samples from two monitoring wells.

3.1.1 Surface Water Monitoring Program Description

Surface water samples were collected and analyzed for BOD, COD, boron, MBAS, pH, phenols, suspended solids, and total recoverable petroleum hydrocarbons (TRPH). The sampling locations for surface water are shown in Figure 8 and are described as follows:

- **Browns Creek—Upstream From Yard** (H)

This sample location is to the west of the TOFC area, in the stream channel segment of the East Fork of Browns Creek which lies at the bottom of the storm water attenuation basin. Samples collected during normal flows represent the water quality in the East Fork upstream of CSXT activities. Rainfall from the TOFC area drains to this area during storm events.

- **Roundhouse Area Storm Sewer** (D)

The sampling location for this sample, and the other two storm sewer samples, is the storm sewer junction manhole located near the TOFC office on the north-eastern side of the

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(2)

site. The sample for the roundhouse area drainage is taken from inside the main 36-inch-diameter storm sewer that flows to this point. The sample represents water quality conditions downstream from the oil recovery manhole and therefore helps to determine the effectiveness of that structure. This storm sewer is the oldest on the site, with the eastern segments dating back to 1917. It carries flows from the majority of the suspected contamination source areas.

- Classification Yard Area Storm Sewer (I)

This sample is taken from inside the classification yard storm sewer at the storm sewer junction manhole. While this sewer drains a relatively large portion of the site, there are no significant sources of contamination known within this area.

- TOFC Area Storm Sewer (G)

The sampling location is the same sewer junction manhole described above, but the sample is collected from within the third sewer which carries flows from the western side of the site as well as the upstream flow from the East Fork of Browns Creek.

- Browns Creek—Downstream From Yard (F)

This sample location is beyond the CSXT property, approximately 250 yards to the northwest of the TOFC area. All water drainage from the site and upstream flow of the East Fork pass through this point. This sample is collected from the first riffle on the downstream side of the temporary oil absorbent booms and containment booms that are used at this location.

3.1.2 Groundwater Monitoring Program Description

Groundwater sampling locations are also shown on Figure 8; samples are collected and analyzed for boron, TRPH, PCBs, pH, volatile organics (benzene, toluene, and xylene), and heavy metals such as cadmium, chromium, copper, nickel, lead and zinc. Turbidity and temperature were also measured. The two monitoring well locations are described below.

- Diesel Storage Tank Area (A)

A 4-inch monitoring well is located in the northeastern corner of the containment berm for the large, 500,000 gallon diesel storage tank on the eastern side of Radnor Yard. The well was installed by an EPA contractor in the mid-1980s during an investigation of an adjacent site.

- Lube Oil Storage/Pump Area (B)

A temporary 2-inch-diameter monitoring well was recently (1990) installed on the south side of the lube oil pump house, to the east of the roundhouse. This well is just south of the lube oil storage tank area and was installed to investigate potential migration of spilled lube oil.

3.2 INVESTIGATION AND MAPPING OF SITE DRAINAGE SYSTEMS

3.2.1 Mapping of Drainage Systems

There are four major sewer systems on the Radnor site. These include the storm sewer, sanitary sewer, free-oil and emulsified-oil collection systems. The first two collection systems include segments that date back to the first operations at the site. The latter two are reasonably recent.

One of the first tasks performed on this project was to develop new sewer maps for the site. Copies of early sewer maps were available and used as an initial base map. Information was added, or removed, based on other later drawings that were available. Site visits were made to establish existing drainage points on-site, and discussions were held with maintenance personnel.

This process confirmed that many of the drainage routes had been altered over the years. Typically older pipes were abandoned and disconnected but left in place. The destination of problem lines was determined by dye tracing and smoke testing. However, this was not successful at all locations and a few questions still remain. This mapping did not include the warehouse areas north of Veritas, previously associated with the CSXT Nashville Division operations.

Maps have been prepared showing the drainage systems, and these have recently been included in the CAD map being developed for the site. Figure 9 shows the site drainage systems.

3.2.2 Storm Water Drainage Investigations

After the draft site drainage maps had been developed, the site was walked to determine the surface drainage pathways to the storm sewer inlets and the conditions of the storm sewer pipes. Areas of the site were designated as permeable or impermeable, mapped and the respective areas calculated. This data was necessary to evaluate the nature of the storm water runoff response from the site. With this information, a better estimate of the peak storm water flow can be developed which will be used to evaluate equipment sizing and costs for the remedial alternatives.

3.2.3 Main Sewer Investigations

A preliminary exploration of the 36-inch diameter main storm sewer which lies in an east–west alignment beneath the engine house, locomotive service/waiting tracks and car shop area was performed in late August to assess the condition of this pipe. Old sewer plans indicate that a portion of this line was installed prior to 1917. This sewer was believed to carry a significant proportion of the petroleum products released with storm water discharges from the site to the East Fork of Browns Creek.

The purpose of this work was:

1. To determine the type and condition of this sewer, and the condition of the joints.
2. To locate, as far as possible, the positions of connecting sewers, holes, leaks, and any other potential inflow or outflow areas.
3. To evaluate the feasibility of conducting a television camera survey of this section of sewer.
4. To sample and analyze, if possible, any incoming water streams.
5. To determine the feasibility of slipping a smaller diameter (i.e., 18 to 24-inch) storm sewer through the existing line.

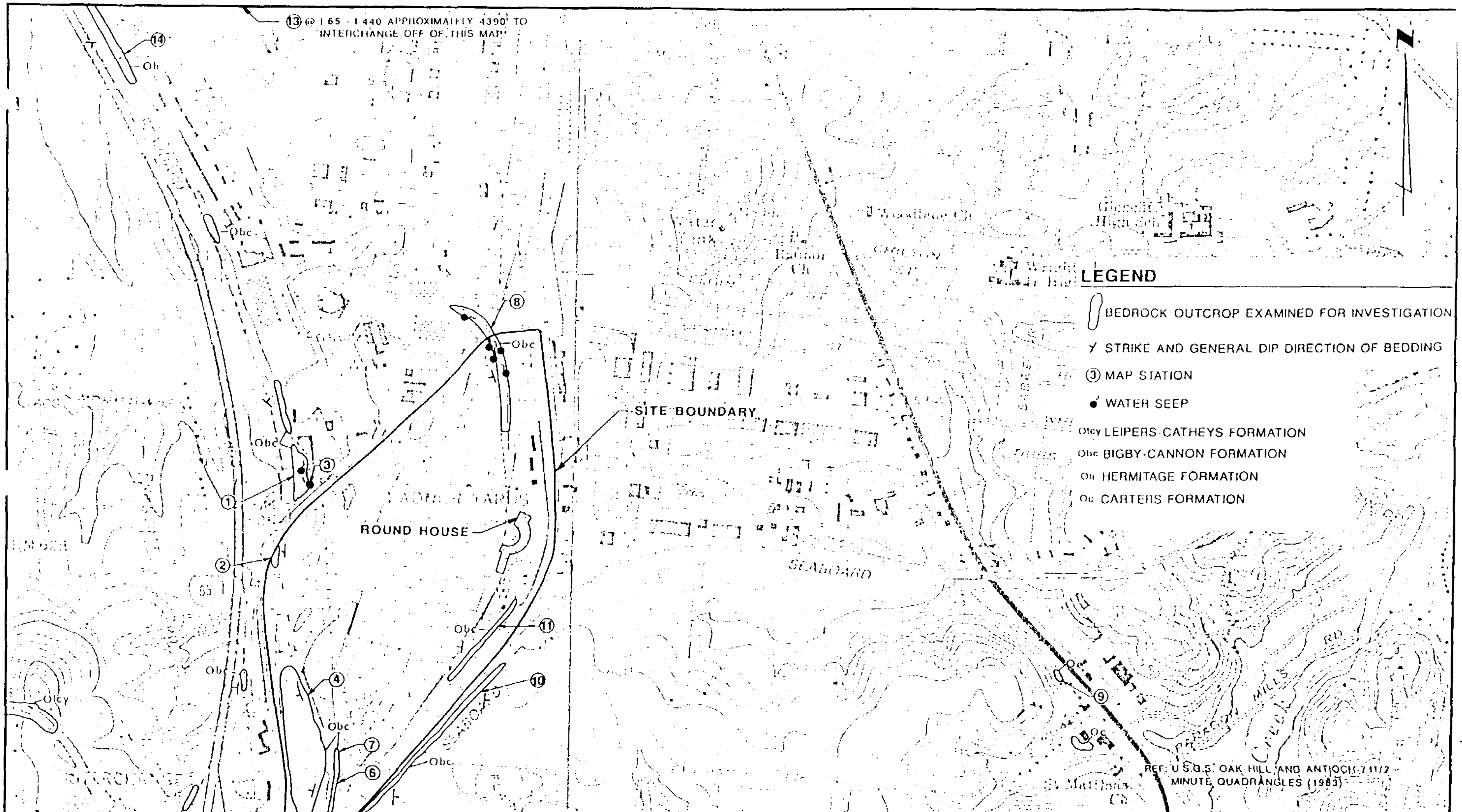
The investigation was limited to the section of main storm sewer east of the oil recovery lift station and the 2-ft by 2-ft box culvert which parallels the tracks on the eastern side of the car shop area. The main sewer was entered at two locations—at the oil recovery lift station west of the car shop and engine house, and also at the manhole on the bank to the east of the roundhouse. The maximum possible distance that could be traveled from the entry point was about 220 feet, due to limitations in air supply line length. Actual distances traveled were less than this due to conditions inside the sewer pipes.

Prior to each sewer entry, a rescue tripod and winch was set up over the manhole. The manholes were force-ventilated with fresh air for approximately 30 to 40 minutes before entry. Air quality was checked with an Exotox monitor to determine whether oxygen and hydrogen sulfide concentrations, and explosive limits, in the confined space were hazardous. The monitor indicated that oxygen levels were below 19.5 percent at the oil recovery manhole, and supplied-air respirators were used for all subsequent entries. The primary investigator moved through the storm sewer, relaying his observations through the radio system. He also collected samples and took some photographs. A discussion of the findings of the sewer investigation is presented in Section 4.2.2.

3.3 SITE GEOLOGY AND HYDROGEOLOGY INVESTIGATIONS

3.3.1 Geologic Mapping Program

Detailed geologic mapping of the Radnor Yard was conducted by Golder Associates geologists during the week of November 6, 1990. The purpose of the field mapping program was to determine the geology of the area underlying the site, especially as it pertains to the presence of groundwater beneath the site. Since bedrock outcrops are limited in exposure within the site area, the areas adjacent to the site were also investigated (Figure 10). During the field mapping program the lithology of the units encountered was



Golder Associates, Atlanta, Georgia		TITLE: SITE AREA BEDROCK GEOLOGY		
CLIENT/PROJECT: Resource Consultants		DATE	SCALE: AS SHOWN	JOB NO: 903-3174
DRAWN: GEH	CHECKED	REVIEWED	FILE NO: 903-3174	DWG NO / REV NO: 2	FIGURE: 10

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described, data were gathered on joint patterns, including orientation, spacing and continuity, and evidence of karst morphology and groundwater seeps was documented. Results of the geologic mapping program are presented in Section 4.3.2. Field notes are included in Appendix A.

3.3.2 Soil Boring Program

The soil boring program was conducted between November 14, 1990, and January 18, 1991. The program was supervised by a Golder hydrogeologist who oversaw the drilling and sampling of 20 boreholes (Figure 11). Two drilling subcontractors were utilized to complete the soil boring program. Layne Environmental Services (Layne) began the drilling program on November 15, 1990, and Miller Drilling Company (Miller) took over on December 18, 1990.

Layne used a Gus Pech 1000R drilling rig, and Miller used a Schram T-450, both of which can auger, air hammer, and air rotary drill. Layne completed all the boreholes except for BH-8 and BH-10 which Miller completed. The boreholes were drilled using all three techniques mentioned above. Temporary 6-inch diameter PVC flush joint casing and 6-inch diameter mild steel casing were used on many boreholes to prevent collapse.

The boreholes were drilled several feet into the limestone bedrock, unless a significant amount of perched groundwater was encountered in the clayey silt layer directly above the bedrock, as in borehole BH-3A. Borehole BH-3A was drilled to the top of bedrock and terminated. Table 1 is a summary of borehole completions.

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TABLE 1

BOREHOLE SUMMARY
CSX RADNOR RAILWAY/NASHVILLE, TENNESSEE

Borehole Number	Date Borehole Completed	Land Surface Elevation (ft MSL)	Total Boring Depth	Elevation Bottom of Boring (ft MSL)	Top of Silt (ft MSL)	Top of Limestone (ft MSL)	Approx. W.L. Open Hole (ft MSL)
BH-1	11/27/90	582.0	23.5	558.5	579.0	569.1	574.1
BH-2	11/28/90	601.0	34.0	567.0	579.0	575.5	576.9
BH-3	11/16/90	604.0	39.7	564.3	580.0	569.0	581.1
BH-3A	1/15/91	600.0	30.0	570.0	579.0	570.0	579.8
BH-4	12/11/90	595.0	39.6	555.4	583.5	558.4	573.7
BH-5	11/18/90	600.7	37.0	563.7	581.5	569.2	581.4
BH-5A	1/16/91	600.7	55.0	545.7	579.7	570.0	575.5
BH-6	11/19/90	586.2	42.0	544.2	582.2	550.0	572.1
BH-7	11/29/90	600.6	34.0	566.6	N/D	573.1	576.9
BH-8	1/17/91	598.2	43.0	555.2	567.2	561.2	573.0
BH-9	11/27/90	600.7	37.0	563.7	579.2	575.7	578.7
BH-10	1/08/91	588.6	53.0	535.6	563.6	560.8	569.4
BH-11	12/03/90	594.9	59.0	535.9	569.4	542.7	571.2
BH-12	12/04/90	596.5	55.0	541.5	N/D	595.7	559.7
BH-13	12/03/90	598.5	9.0	589.5	N/D	598.5	594.2
LBH-1	11/17/90	598.6	35.0	563.6	N/D	571.3	571.3
LBH-2	11/17/90	598.6	17.0	581.6	N/D	N/R	N/R
LBH-3	11/20/90	598.6	35.0	563.6	N/D	566.5	573.9
DT-1	11/20/90	582.5	29.0	553.5	580.9	555.8	572.5
DT-1A	11/16/90	582.6	9.0	573.6	580.9	N/R	N/R

NOTE: (ft MSL) = (feet, mean sea level)
BH = Borehole
LBH = Lube oil borehole
DT = Diesel tank borehole
N/D = Not detected
N/R = Not reached by drilling
BH-3, BH-3A, and BH-5 water levels are from the perched water in the silt zone.

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Soil was sampled in the boreholes on five-foot centers with two-inch and three-inch diameter split spoons. The soil samples were logged in the field by the field hydrogeologist, and boring logs were prepared. Boring logs are included in Appendix B. The drill cuttings were placed in barrels and deposited in a secure marked area set up by CSXT.

Rock core samples were taken in boreholes BH-3, BH-4, BH-5, BH-6, BH-11 and BH-12. The rock core runs were five feet and were logged by the field hydrogeologist. The core descriptions are included on the boring logs in Appendix B. The core samples are currently stored in Golder Associates' Atlanta office.

PVC screen and riser were placed, but not sealed, in the open borehole, and the following day the groundwater sample was taken and the water level was measured. The screen and riser were then removed and the full length of the borehole was grouted. Results from the soils and groundwater chemical analyses are discussed in Section 4.4.

Decontamination of the equipment and drilling rig were completed between boreholes using a high pressure steam cleaner, Isopropanol, Alconox, and distilled water, to prevent cross-contamination between each borehole. Borehole locations were surveyed to the nearest 0.01 foot in elevation and to the nearest 0.1 foot in ground surface location by Adams and Company Surveyors of Nashville, Tennessee.

3.3.3 Piezometer Program

Six piezometers were installed to obtain groundwater levels and samples (Figure 11). Four of the piezometers (P-1, P-2, P-3, and P-4) were screened in the limestone bedrock and two piezometers (P-5 and P-6) were screened in the natural clayey silt zone overlying the limestone bedrock.

The piezometers were installed in boreholes which were drilled, sampled and logged in the same manner as the other 20 boreholes drilled for this program. Rock cores were taken at the locations of piezometers P-2, P-3 and P-4. Decontamination procedures were the same as those used for the borehole program. The piezometers were constructed of 2-inch diameter, flush-threaded PVC pipe and 0.010-inch slotted well screens. A 20/40 sand pack was placed around the screen, a bentonite seal was placed above the sand pack, and Portland Cement/Quikcrete was used to backfill the borehole, complete the seal and set the flush mounted steel protective covers. As within the boreholes, the piezometers were surveyed to the nearest 0.01 foot in elevation and to the nearest 0.1 foot in ground surface location. The piezometer installation logs are presented in Appendix C. Table 2 is a summary of piezometer construction data.

The piezometers were developed using a Westinghouse Arch well pump and manual bailing. Inert nitrogen was used to force the water from the piezometer casing through the pump to the surface. Dedicated polyflex tubing was used for each piezometer to prevent cross-contamination. Specific conductance, pH and temperature were measured several times during development and development continued until these parameters stabilized. Decontamination procedures were utilized during development to prevent any contamination of piezometer water. Piezometer development records are provided in Appendix C.

Water level measurements were taken from available piezometers and existing wells on three occasions during the investigation. Groundwater levels from all piezometers on site were measured, using a SINCO electric water level indicator and engineer's rule, on January 30, 1991, upon completion of the field drilling program.

TABLE 2

PIEZOMETER CONSTRUCTION SUMMARY
CSX RADNOR RAILWAY/NASHVILLE, TENNESSEE

Piezometer Number	Date Well Completed	Top of Piezometer Casing** (ft MSL)	Land Surface Elevation (ft MSL)	Total Boring Depth	Elevation Bottom of Boring (ft MSL)	Top of Silt (ft MSL)	Top of Limestone (ft MSL)	Screen Interval (ft MSL)	Sand Pack Interval (ft MSL)	Bentonite Seal Interval (ft MSL)
P1	12/27/90	600.20	600.2	51.0	549.2	578.8	567.2	549.9–554.9	549.2–561.7	561.7–569.7
P2	1/09/91	592.24	592.3	65.0	527.3	586.3	564.8	537.7–547.7	527.3–549.4	549.4–553.0
P3	12/14/90	595.60	595.5	95.0	500.5	568.0	562.0	505.5–525.5	500.5–528.2	528.2–531.2
P4	12/11/90	596.59	596.6	92.0	504.6	555.6	539.1	510.0–525.0	504.6–528.4	528.4–532.6
P5	12/19/90	596.28	596.3	58.0	538.3	N/D	538.3	546.3–556.3	542.3–558.8	558.8–561.2
P6	1/05/91	592.40	592.3	27.5	564.8	586.3	564.8	567.1–577.1	566.8–579.2	579.2–580.9

NOTE: N/D = Not detected
** Top of PVC used as reference point for groundwater level measurements.
(ft MSL) = (feet, mean sea level)
Piezometers P5 and P6 are screened in the clayey silt layer.

Hydraulic conductivity (K) testing was conducted in the piezometers to determine the in situ horizontal hydraulic conductivity values for the limestone bedrock and the overlying silt layer. Rising head tests were performed on all piezometers except for P-5, which has no water. The tests were conducted by rapidly bailing several gallons of water from the piezometer and measuring the recovery with a SINCO electric water level indicator and an engineer's rule.

The Cooper, Bredehoeft and Popadopulos method for confined aquifers (1967) was used to evaluate the rising head tests for the limestone piezometers. Hvorslev's method for unconfined aquifers (1951) was used to determine the K value from the P-6 rising head test. The rising head test data and analyses are presented in Appendix D.

3.4 SITE SUBSURFACE CONTAMINATION INVESTIGATIONS

3.4.1 Soil Sampling Methodology

A key task in the site subsurface investigation was to assess the potential contamination at the suspected source locations shown in Figure 12. As noted in Section 3.3.2, the general procedure for soil sampling called for collection of samples at five-foot increments of depth. In practice, the sampling increment varied according to the nature of the material being drilled and the ability of the drillers to retrieve samples in the split-spoon tube. Some sample retrieval problems occurred at areas where unconsolidated or loose fill material were encountered. The use of sand catchers improved sample retrieval efficiencies.

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Each soil sample collected was checked visually and for odor to assess the potential for TRPH contamination. All samples were analyzed for TRPH levels using the infra-red method. The samples which exhibited the strongest petroleum-related odor were also tested for the following parameters:

- heavy metals (antimony, arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc), which could reflect the presence of waste oils;

- benzene, ethylbenzene, toluene and xylene, which could indicate the presence of gasoline spills, and might also indicate the presence of high concentrations of very fresh diesel fuel;

- boron, which could indicate the presence of engine coolant compounds;

- volatile and semi-volatile organic pollutants, which could indicate the presence of compounds of diesel fuel or pollutants from some other source. The organic Priority Pollutant list was used for the analysis of the majority of the samples. However, the Hazardous Substance list was used for analysis at boreholes BH-3, BH-5, and BH-6 to screen for a more extensive range of compounds. Table 3 presents a list of analyzed compounds.

In addition to the above parameters, total solids content was measured in order to be able to compare results on a dry-weight basis.

TABLE 3

PRIORITY POLLUTANT AND HAZARDOUS SUBSTANCE LIST

Volatiles

* Acetone
Benzene
Bromoform
* Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chlorodibromomethane
Chloroethane
2-chloroethylvinyl ether
Chloroform
Dichlorobromomethane
1,1-dichloroethane
1,2-dichloroethane
1,1-dichloroethylene
1,2-dichloropropane
1,3-dichloropropene
Ethylbenzene
Methyl bromide
Methyl chloride
* Methyl ethyl ketone
* Methyl isobutyl ketone
Methylene chloride
* Styrene
1,1,2,2-tetrachloroethane
Tetrachloroethylene
Toluene
1,2-dichloroethylene
1,1,1-trichloroethane
1,1,2-trichloroethane
Trichloroethylene
* Vinyl acetate
Vinyl chloride
* Xylenes

Acid and Base/Neutral Extractables

2-chlorophenol
2,4-dichlorophenol
2,4-dimethylphenol
4,6-dinitro-o-cresol
2,4-dinitrophenol
2-nitrophenol
4-nitrophenol
P-chloro-m-cresol
Pentachlorophenol
Phenol
* 2,4,5-trichlorophenol
2,4,6-trichlorophenol
Acenapthene
Acenaphthtylene
Anthracene
Benzidine
Benzo(a)anthracene
Benzo(a)pyrene
* Benzo(a)fluoranthene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
* Benzoic Acid
* Benzyl Alcohol
Bis-2-chloroethoxymethae
Bis(2-chloroethyl) ether
Bis(2-chloroisopropyl) ether
Bis(2-ethylhexyl) phthalate
4-bromophenyl phenyl ether
Butyl benzyl phthalate
* 4-chloroaniline
2-chloronaphthalene
4-chlorophenyl phenyl ether
Chrysene
Dibenzo(a,h)anthracene
* Dibenzofuran
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
3,3-dichlorobenzidine
Diethyl phthalate
Dimethyl phthalate
Di-n-butyl phthalate
2,4-dinitrotoluene
2,6-dinitrotoluene
Di-n-octyl phthalate
1,2-diphenyl-hydrazine
Fluoranthene
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
2-Methylphenol
* 2-Methylnaphthalene
* 4-Methylphenol
Naphthalene
* 2-Nitroaniline
* 3-Nitroaniline
* 4-Nitroaniline
Nitrobenzene
N-nitrosodimethylamine
N-nitrosodi-n-propylamine
N-nitrosodiphenylamine
Phenanthrene
Pyrene
1,2,4-trichlorobenzene

Pesticides and PCB's

Aldrin
Alpha BHC
Beta BHC
Gamma BHC
Delta BHC
Chlordane
4,4-DDT
4,4-DDE
4,4-DDD
Dieldrin
Alpha endosulfan
Beta endosulfan
Endosulfan sulfate
Endrin
Endrin aldehyde
* Endrin ketone
Heptachlor
Heptachlorepoxide
* Methoxychlor
PCB 1242
PCB 1254
PCB 1221
PCB 1232
PCB 1248
PCB 1260
PCB 1016
Toxaphene
2,3,7,8-Tetrachlorodibenzo-P-Dioxin (TCDD)

<u>INORGANIC</u>*

* Aluminum
Antimony
Arsenic
* Barium
Beryllium
Cadmium
* Calcium
Chromium
* Cobalt
Copper
Cyanide
* Iron
Lead
* Magnesium
* Manganese
Mercury
Nickel
* Potassium
Selenium
Silver
* Sodium
Thallium
* Vanadium
Zinc

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* These compounds are <u>NOT</u> included on the Priority Pollutant List.
* The Priority Pollutant list also includes asbestos.

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3.4.2 Groundwater Sampling Methodology

Groundwater samples were collected from boreholes whenever encountered during the drilling program. The groundwater samples were collected, as described in Section 3.3.2, after a temporary PVC screen had been placed in the borehole and the suspended sediments had been allowed to settle overnight. The sample was collected using teflon bailer and was the first aliquot removed from the borehole. The sample should therefore be indicative of the groundwater conditions at that particular location. Groundwater samples were analyzed for the same parameters described above.

Groundwater samples were also collected from the piezometers. In this case, the screens were permanently set as described in Section 3.3.3. Three well volumes of groundwater were removed from the piezometers and sampling was performed the following day. This procedure allows any potential TRPH in the vicinity of the piezometer the time to reform on the surface of the groundwater before sampling. The sample of groundwater collected in the first bailer was placed in a wide-mouthed, glass 1-liter container for TRPH analysis. Other samples were collected in sample containers and preserved according to the recommended procedures for the selected analyses.

3.5 IDENTIFICATION AND ASSESSMENT OF SURFACE CONTAMINATION SOURCES

There are extensive areas of track pans around the roundhouse and locomotive shop which collect the heaviest oil leakage from locomotives which are parked or idling while awaiting servicing. The collected oils and any storm water that may also collect on the pans are routed via cross-drains and industrial sewers to either the free oil or emulsified oil wastewater treatment facilities. These track-panned areas and cross-drains were surveyed for damaged sections and/or blockages. In addition, areas where heavy surface contamination of the ballast can be observed were noted. Ballast was removed by shovel to a depth of about 1 foot and samples collected for TRPH analyses. The objective of this work was to evaluate the potential of the contaminated surface ballast material as a significant source for subsurface and groundwater contamination.

In addition to the track-pan areas, inspections were performed at the diesel tank area, the lube storage area, the oil storage tank to the south of the locomotive shop, and the API separator, recovered oil holding tank and sand beds located to the north of the emulsified oil treatment facilities.

3.6 ASSESSMENT OF FREE-OIL WASTEWATER TREATMENT FACILITIES

Oily wastewaters that are collected by the track pans are treated in a series of lagoons with grit and oil removal equipment. The large (lower) free-oil lagoon was designed for flow equalization. Effluent from the lagoon passes through a vertical tube oil separator before discharging to the Metro sewer system. If the pumps for the sanitary sewer line are not functioning, flow from the lagoon overflows and is diverted into the storm water sewer system.

Oil that is intercepted at the oil recovery manhole west of the car shop is also pumped via force main to the free-oil wastewater treatment facility. During storm events, the pump conveys (unless manually overridden) mainly storm water to the free-oil system. This additional flow has a significant impact on the performance of the free-oil treatment system, and can dramatically reduce the flow equalization capabilities of the large lagoon. This, in turn, increases the potential for the oily wastewater to overflow back into the storm water system. If manually overridden, the pump does not operate and oily storm water flows down the storm sewer to Browns Creek.

An analysis of the pumping capacities of the pumps for both the oil recovery pump station and the Metro sanitary sewer system was performed to establish the maximum flows that can be handled by these systems. Free-oil wastewater treatment equipment and the lagoon liner have been periodically inspected to determine their condition and serviceability. The oil recovery manhole was entered and as-built measurements of the structure and piping made. The design of this unit is being reviewed. In addition, the buildup of grit and sludge in the upper free-oil lagoon has been quantified and sampled.

4.0 Phase I Findings

4.1 INTERIM MONITORING PROGRAM

Results of the five-month interim monitoring program have been included as Appendix E. The data shows that the concentrations of the water quality parameters tested were typically near the practical quantification limit for the respective tests. The 1990 summer period was very dry and had few significant precipitation events. The data is therefore representative of normal flow conditions in the East Fork.

An analysis of this data is difficult due to relative errors introduced at these low concentrations. Comparison of the results suggests there is little significant difference between the water quality upstream of Radnor Yard and that coming from CSXT operations under normal (low) stream flow conditions. The upstream water quality during the first sampling event was worse than normal, possibly due to a discharge from an upstream industry. Almost all of the parameters tested were elevated above the ranges encountered during subsequent sampling events. The roundhouse sewer perhaps demonstrated the most consistent TRPH values, but these concentrations were not particularly high. The classification yard sewer was consistently cleaner than either the TOFC yard (which includes the upstream Browns Creek flow) or roundhouse sewer flows. The results demonstrated that the oil recovery manhole can perform adequately under low flow conditions.

Groundwater quality of samples collected from the monitoring well at the diesel storage tank area was good, with all parameters being below, or near, method detection limits. The only exception was the TRPH value of 0.89 mg/l in September.

The groundwater level at the lube oil storage area was significantly higher than at the diesel storage tank area and recharged almost immediately after purging prior to sample collection. It is thought that this groundwater may be perched above the natural silt layer. Groundwater quality was not as good as at the diesel tank area. While PCB, and benzene, toluene and xylene have not been detected, the metal concentrations are elevated, although this is probably due to the high amount of suspended solids in the groundwater samples retrieved from this well. TRPH values have been consistently detected, and have ranged between 0.5 and 5.5 mg/l, again, probably due to oils being attached to the surfaces of solid particles in the well water samples. This well has not performed satisfactorily and should be replaced if further study of this suspect perched water system is undertaken.

4.2 SITE DRAINAGE SYSTEM FINDINGS

4.2.1 Storm Water Drainage Investigations

Storm water collected from the buildings and impervious areas around the roundhouse drain via the main storm sewer to the oil recovery lift station. This flow is expected to carry the highest loads of petroleum products. Turbulence in the sewer from the high flows, as well as from the storm water collected along side the road on the eastern side of the classification yard and falls into the manhole, mixes with petroleum substances and drastically reduces the efficiency of the baffled manhole. Under these conditions, the petroleum substances can easily pass under the baffle and flow into the East Fork.

Storm water collected from the oil pans, locomotive servicing areas and other more contaminated areas drains to the free-oil wastewater treatment system. This system consists of a grit removal tank, an (upper) oil skimming lagoon and the (lower) large, surge lagoon. Oil is collecting in the surge lagoon, which indicates that the equipment in the grit removal and oil skimming tank/lagoon is not completely effective. Some of the equipment may need repair or refurbishing. From the surge lagoon, storm water flows through a vertical tube coalescer (VTC) unit and then to the city sewer. The tube pack within the VTC unit have been removed and need to be replaced (or the VTC itself should be replaced).

When the surge lagoon is full it overflows into the roundhouse storm water sewer pipe. Any floating oil on top of the surge lagoon will drain off with the first overflow unless the wind is from the north which keeps the oil at the south end of the lagoon (the general wind direction is out of the southeast). The skimming baffle that has been placed at the overflow structure is not adequate to prevent oil from draining off the surface of this pond.

The classification yard is partially drained by the classification yard and roundhouse storm sewers although the exact configuration of the collection system within the yard area is unknown. The available sewer maps show that there are relatively few storm water collection points to drain such a large and flat area. It is suspected that most of the precipitation infiltrates into the underlying fill material where it is stored and slowly drains through the subsurface along the original valley floor. The slow subsurface drainage stretches out the storm water discharge from the site after major storms for long periods (weeks). The infiltration could potentially carry any petroleum contamination in the subsurface fill toward the discharge point.

During significant storm conditions, storm water runs off the TOFC area and discharges into the retention basins to the west of the site. This flow path somewhat attenuates the storm water peak flow from the TOFC site. Some degradation of water quality is expected during the initial storm flush of the TOFC area, but this should be typical of road or parking lot runoff. This area is used for storing, loading and unloading containers and trailers.

4.2.2 Storm Sewer Investigations

4.2.2.1 Storm Sewer Observations

A strong, diesel fuel odor was immediately noticed when the oil recovery manhole on the road to the east of the classification yard was entered. The atmosphere in the bottom of the manhole was oxygen deficient. There was some accumulated grit at the bottom of the manhole. Flow into the manhole from the 36-inch storm sewer was approximately 4-inches deep (estimated at about 100 gallons per minute) even though there had been no significant rain events for several weeks prior to this investigation.

The joints, occurring every 10 feet, appeared to be in reasonable condition for the first 30 feet. At about 43 feet from the entry point, the water elevation in the sewer increased to more than 18 inches deep, preventing the investigator from continuing. The increase in water elevation in the sewer was apparently due to a low spot or "swag" in the line's horizontal profile. Approximately 20 feet further into the pipe, water was observed entering a fracture along the crown of the pipe, presumably at a joint location. Other leaks at fairly regular intervals were also observed extending beyond this point, most likely at joint locations.

A second entry was made at the manhole on the embankment east of the access road adjacent to the diesel shop. Standing water was found in the bottom of the storm sewer line within 10 feet of the entry manhole, with water trickling in at the first joint. Water depth increased to about 6 inches at the next joint due to a joint displacement and an accumulation of gravel at downstream joint locations.

Joint separations and displacements of ½-inch were common along this pipe. Gravel accumulated at the bottom of the pipe appeared to be primarily due to concrete spalling from the inside of the pipe. At some locations the concrete was quite brittle. Water was observed leaking through most of the joints along this length.

At approximately 125 feet from the entry manhole, a power transformer pole was found protruding into the sewer pipe. This location is at the eastern side of the Diesel Shop. However, there did not appear to be any water or oil entering the sewer through the hole alongside the pole.

Cracks along the crown of the sewer pipe were observed in many of the pipe segments from 182 feet, directly under the eastern-most track inside the Diesel Shop, to about 215 feet which corresponded to the western wall of the diesel shop. An oil sheen was observed on standing water at 194 feet. Samples were collected and analyzed for TRPH concentrations. The investigator could not proceed further beyond the 215 feet distance.

The third and final entry was into the box culvert at the manhole located on the eastern side of the Car Service Building and northwest of the turntable. The investigation of the culvert extended in two directions from this point—about 60 feet to the north and about 200 feet to the south.

In general, the culvert was in good structural condition. The culvert is constructed of concrete and cast continuously without joints. No significant leaks or damaged areas were located. There was a considerable amount of heavy oil in the standing water along the bottom of the culvert.

At the north (or upper) end of the culvert, the culvert stops and three pipes enter. The middle pipe is approximately 8-inches in diameter and appeared to be plugged by an orange-brown, spongy mass. The other pipes were clear. There was also a pipe entering the culvert from the eastern side about 8-feet downstream from the culvert's upper end. A small trickle of water into the culvert was observed in this vicinity.

An 8-inch diameter pipe was found 180 feet to the south of the entry manhole, entering from the east side. This has been tentatively identified as coming from the drain at the bottom of the turntable pit. No other pipes were found entering the culvert.

4.2.2.2 Storm Sewer Sampling Results

Four samples were collected from the main storm sewer just upstream from the oil recovery lift station for Total Recoverable Petroleum Hydrocarbon (TRPH) and residual chlorine analyses. TRPH concentrations were evaluated using two methods: gravimetric and gas chromatography (GC). The GC method measures petroleum compounds in the sample relative to gasoline and diesel fuel oil standards. As the reference standards are mixtures of relatively light petroleum compounds, some of the heavier compounds are not measured in this procedure. These two procedures are different and do not necessarily produce similar TRPH values.

Residual chlorine measurements were made to determine if incoming streams originate from nearby water lines. This method is only successful, however, if the water entering the sewer comes from a nearby water line and has minimal contact with soils or other waters containing organics. Time and organics will deplete the residual chlorine.

The TRPH results for the sample collected of the water flowing into the oil recovery manhole were 73 and 25 mg/l for the gravimetric and GC methods, respectively. These sample results represent relatively high TRPH levels, and indicate that the majority of the petroleum compounds are heavier than fresh diesel fuel, most likely heavily weathered diesel fuel or oils. The diesel fuel odor at the lift station manhole, however, indicates that some reasonably fresh diesel fuel is present.

The first two of three samples collected from the eastern end of the main storm sewer were streams of water infiltrating through open joints or cracks in the pipes. These samples appeared reasonably clean, and show lower TRPH levels than at the oil recovery manhole. The TRPH GC result for sample 1 was less than 0.5 mg/l; the GC result for sample 2 was 2.5 mg/l. TRPH values determined by the gravimetric method were less than 10 ppm for both samples.

The third sample was collected from the bottom of the sewer, approximately 180 feet west of the entry manhole. The TRPH values for this sample were 33 and 60 mg/l for the GC and gravimetric methods, respectively. These concentrations and GC-to-gravimetric ratio are similar to the sample collected at the oil recovery manhole.

No samples were collected from the 2-ft by 2-ft culvert which parallels the tracks next to the car shop area. The bottom of the culvert was visibly very oily and sampling was not necessary to confirm this.

4.2.2.3 Discussion of Findings

The diesel fuel odor and oxygen-deficient conditions at the oil recovery manhole indicate that a significant amount of petroleum product is finding its way into this storm sewer line. The oil recovery manhole was designed to remove floating oils but is not effective in removing attached (to solid particles) or emulsified oils. These compounds are carried with the main flow beneath the baffle. Oils which are absorbed to solid particles sink to the manhole bottom and are eventually washed or flushed beneath the baffle and eventually continue down the storm sewer.

The storm sewer investigation revealed that the main storm sewer is in relatively poor condition. There are numerous leaking joints, many of which have separated and become slightly displaced. There has been a more serious pipe failure under the western edge of the car shop tracks; this failure extends an unknown distance to the east. The type of longitudinal pipe failure observed at this location, and also under the Diesel Shop, is a result of the heavy structural loadings from the high fills and overhead locomotive traffic.

The investigation did not identify any one major location that could be considered responsible for the persistent infiltration of water into the storm sewer which occurs even during dry weather periods; rather, the flows appear to be the result of multiple leaks at joints and cracks along this pipe system. However, it should be remembered that only a portion of the total sewer system was physically inspected.

The fact that many of the observed leaks were at the top, or side, of the pipe indicates that the pipe may drain water traveling in the granular backfill which may surround the pipe. A cursory comparison of approximate groundwater depths at the monitoring wells located near the lube oil pump house and the diesel storage tank shows that groundwater levels could have been at, or slightly above, the crown of the storm sewer during this past summer. The results of sampling the infiltrating water suggest that water leaks may be responsible for at least some of the flow.

4.3 SITE GEOLOGY AND HYDROGEOLOGY FINDINGS

4.3.1 Soils

According to the 1981 Soil Survey of Davidson County, Tennessee, the majority of the site is underlain by soils of the Maury-Urban land complex. Typically, the surface layer of Maury soil is a dark brown silt loam extending to a depth of about seven inches. The subsoil extends to an average depth of about 65 inches. The upper part of the subsoil typically is a friable silty clay loam, and the middle and lower part of the subsoil typically is a firm silty clay.

During the soil boring program, naturally occurring soils were encountered just above the limestone bedrock, and the thickness of these soils ranged from zero feet at the locations of boreholes BH-12 and BH-13 on the southwest portion of the site, to approximately 32 feet at the location of borehole BH-6, where a sinkhole is suspected to occur (Wilson and Miller, 1972) (Figure 11). The average thickness of the naturally occurring soils in the roundhouse area is 9.3 feet, as measured in the boreholes. The natural soils overlying the limestone bedrock on site are soft to stiff, brown clayey silts, grading to less clay with depth toward the top of the bedrock. Trace amounts of fine, riverwashed gravel were also noted in many boreholes. These soils were overlain by approximately 1.5 to 41 feet of fill material, used in the construction of the Rail Yard, which was characteristically composed of three components: limestone boulders and gravel, soft to stiff clayey silt, and black, medium to coarse sand-sized cinder.

The fill materials should transmit water readily, although the hydraulic conductivity was not measured. The silty clay should have a lower hydraulic conductivity than the fill. The cation exchange capacity and the total organic content of the fill and the silty clay were not measured during the Phase I investigation.

4.3.2 Geology

Based on the results of the geologic mapping and soil boring programs, the Radnor Yard is underlain by fill materials overlying a mantle of clayey silt, and the underlying Ordovician Bigby-Cannon Formation. All bedrock outcrops on site (Figure 10) contained lithologies characteristic of the Bigby-Cannon Formation whereas other outcrops mapped outside the site are within the Carters Formation (east-northeast of the site), the Hermitage Formation (north of the site) and Leipers-Catheys Formation (west of the site). Previous investigations by Wilson (1949) and Allen (1937) have shown the upper tributaries of the East Fork of Browns Creek, directly beneath the northern classification yard, have eroded into the Hermitage Formation. This area is now inaccessible due to the filling of these valleys in the 1950's. However, field mapping of the rocks within the East Fork of Browns Creek indicates that Bigby-Cannon, and not Hermitage, is exposed by the upper reaches of this tributary (Figure 10). Therefore, the Hermitage is not expected to be exposed beneath the fill at the Radnor Yard. Descriptions of these formations, their relationships to each other, and features such as jointing, bedding and karst geomorphology are presented in some detail in Appendix A; details of the Bigby-Cannon Formation are summarized below.

As previously noted, all of the outcrops within the Radnor Yard boundary are composed of various facies of the Bigby-Cannon Formation. The best exposures are located along the east side of the large knob in the southwestern corner of the yard, behind the large building south of the oil booms in Browns Creek, and in a deep railroad cut located below the Bowl tower, on the southeastern leg of the wye.

The Bigby-Cannon Formation comprises three distinct and mappable facies: 1) Bigby facies, 2) Dove-Colored facies, and 3) Cannon facies. Furthermore, the Bigby facies can be subdivided into an upper, middle and lower facies. Based on this geologic field investigation, only the Bigby and Dove-Colored facies were encountered. This is consistent with the interpreted facies relations described by Wilson (1949). Wilson suggests that the Cannon facies would lie further to the east of the site.

The Bigby facies consists of a blue-gray (when fresh), bioclastic limestone which contains both phosphatic specks and laminae. The laminar phosphates generally weather to a characteristic reddish-brown color. These laminations are characteristic of many of the outcrops observed within the Radnor Yard area.

Based on the isopach maps of the Dove-Colored facies (Wilson, 1949), the Dove-Colored facies at the Radnor Yard is about 12 to 15 feet thick, whereas the Bigby facies is up to 70 feet thick. However, because the Dove-Colored facies occurs as lenses interbedded with the Bigby facies, the thickness may vary from virtually absent to 15 feet at the Radnor Yard.

Based on the borehole and piezometer investigation results, the top of Bigby-Cannon Limestone and top of clayey silt can be mapped to indicate the surface topography prior to the placement of fill at the site. The top of limestone contours (Figure 13) and the top of silt contours (Figure 14) reveal the buried upper stream valley of the East Fork of Browns Creek beneath the western half of the site. The top of the Hermitage Limestone has been estimated, based on the change in drilling cuttings noted during drilling. Figure 15 shows two geologic cross-sections for the site which indicate the extent of fill, clayey silt, Bigby-Cannon Limestone, and Hermitage Limestone expected beneath the site.

Allen (1937) describes the structure of the Browns Creek area as a series of very irregularly shaped anticlines and synclines, suggestive of no pattern in the orientation of their axis. Allen made note of small scale minor faults with little displacement and of joints. During this detailed geologic investigation, Golder Associates did not see any faults at the Radnor Yard, although bedding and joint sets were prevalent.

Bedding was strongly developed at each outcrop at the Radnor Yard and ranged from massive to thinly bedded and planar to irregular to current modified. Throughout the site, bedding was gently dipping with no consistent dip direction (Figure 10). The apparent

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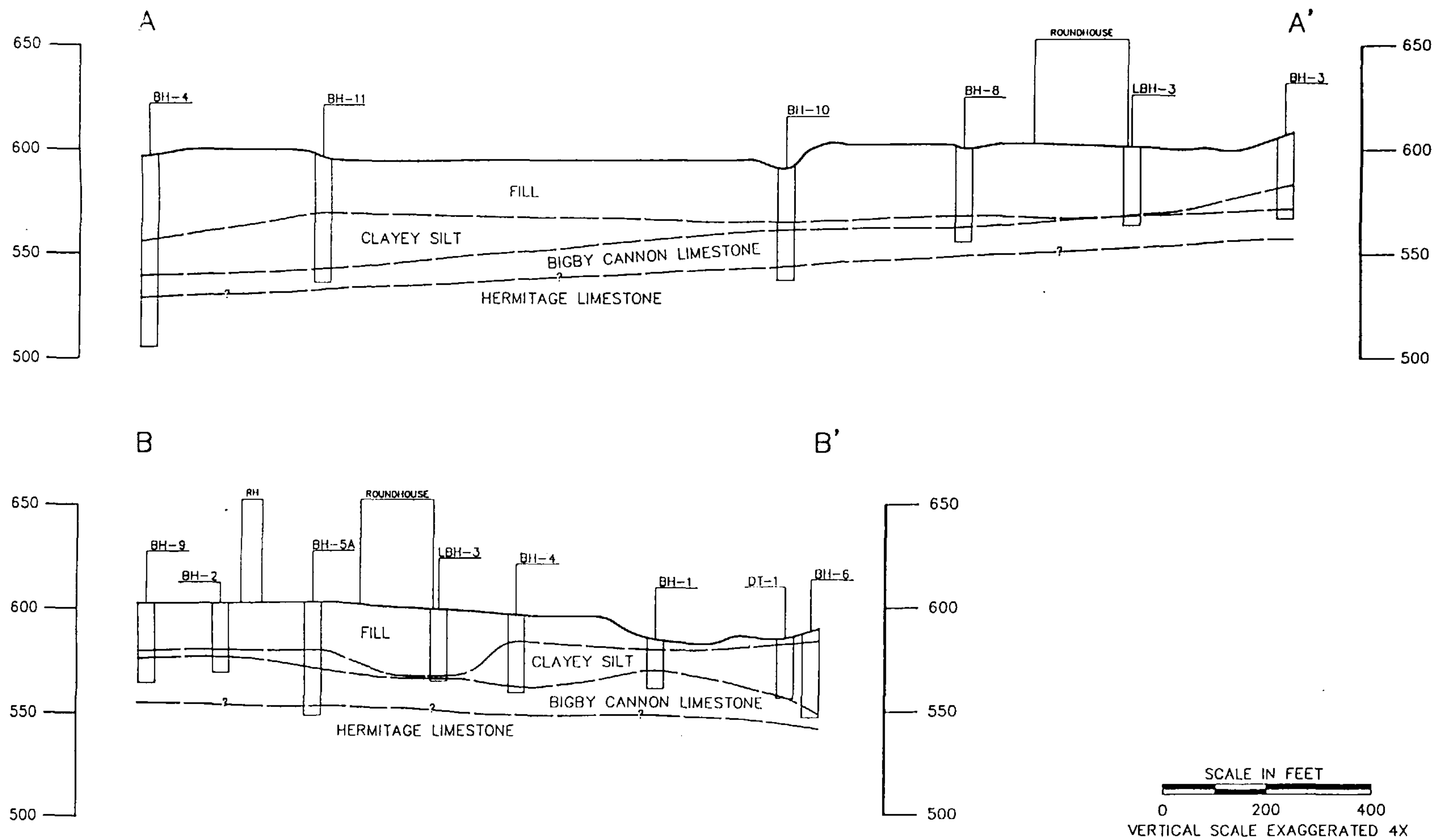


Golder Associates
Atlanta, Georgia

CLIENT/PROJECT: Resource Consultants

TITLE: GEOLOGIC CROSS-SECTION A-A' AND B-B'

DATE 5/6/91	SCALE AS SHOWN	JOB NO. 903-3174
FILE NO. 903-3174	DWG. NO./REV. NO.	FIGURE NO. 15

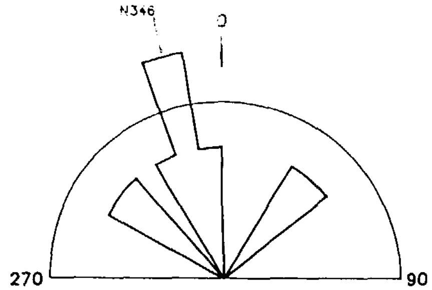
DRAWN GEH	CHECKED	REVIEWED

randomness in bedding dip direction illustrates the presence of small scale, irregular structures which are superimposed on the larger scale Nashville dome. These small-scale flexures can be envisioned as representing a gently dipping undulating surface.

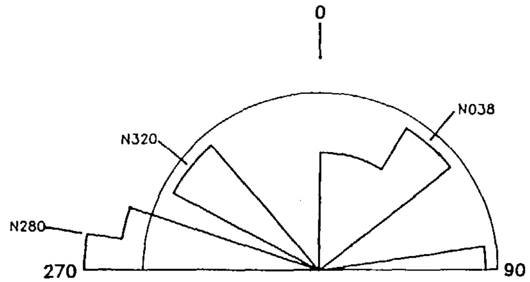
All outcrops within and around the Radnor Yard contain pervasive joint sets. Several prominent sets were measured throughout the area. These joint sets are penetrative on the outcrop scale and throughout all outcrops, thus penetrative on a regional scale. The joint sets for the different outcrops are shown on Figure 16.

Cumulative joint orientations are shown on Figure 17. Rose diagrams are weighted based on the number of joints measured in a particular orientation. Based on the cumulative rose diagrams, two major penetrative joint orientations are noted, N285°-314° and N035°-075°. The orientation of these joints is consistent with joints measured throughout the Nashville dome.

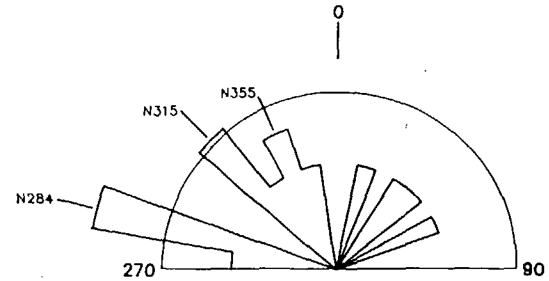
Because bedrock outcrop extent within the Radnor Yard is limited, vertical karst development is not readily observable. Sinkholes are clearly expressed in the Bigby-Cannon limestones exposed along the I-440 road cut south of Nashville, and just west of the I-65 interchange. The development of epikarst (zones of highly corroded bedrock) is pronounced, and because the bedrock dips at very gentle angles, the level of epikarst development is also more or less planar and occurs up to a depth of about 20 feet beneath the ground surface. Bedding planes are solutionally enlarged, and joint faces are scalloped and stained by dissolution of bedrock. The karst is of the sub-soil variety. Soil is well developed on the upper slope of the cut and infills the sinkholes. The largest sinkholes appear to have captured or arrested further development of the other, smaller sinkholes and their necks appear to have penetrated depths beyond the epikarst zone. As the sinkholes enlarged, bedrock ledges collapsed into the enlarging solution cavity thus displaying both



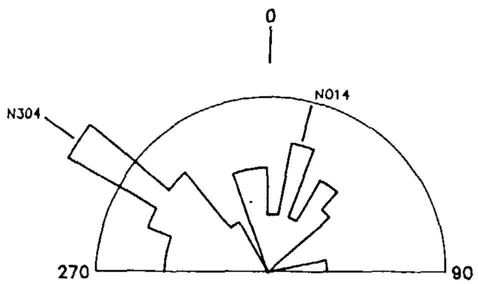
MAP STATION 1,2,3 N=9



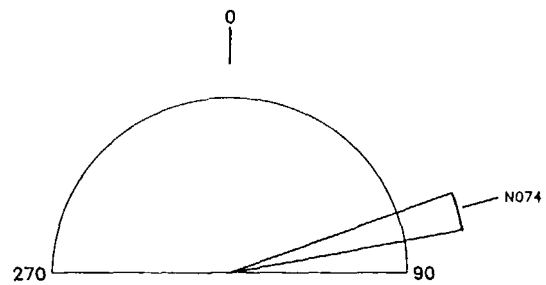
MAP STATION 4,5 N=20



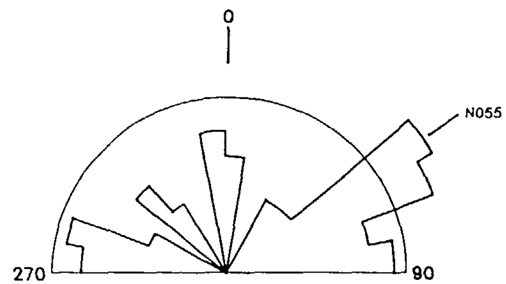
MAP STATION 6,7 N=18



MAP STATION 8 N=52



MAP STATION 9 N=2



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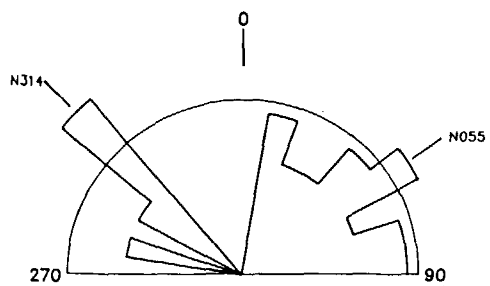
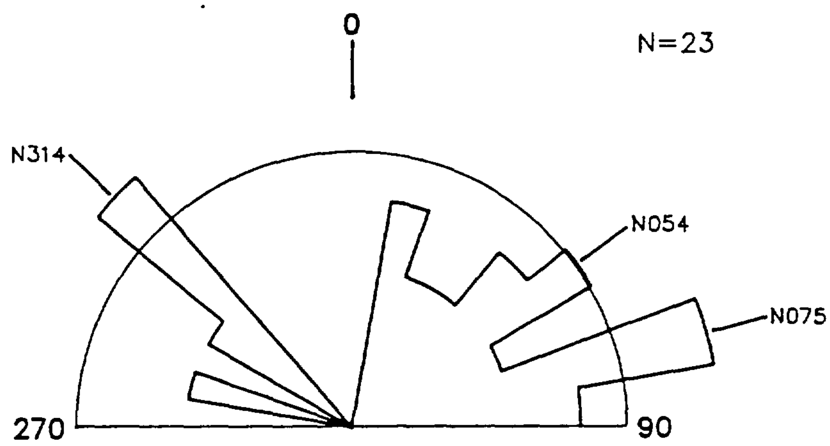
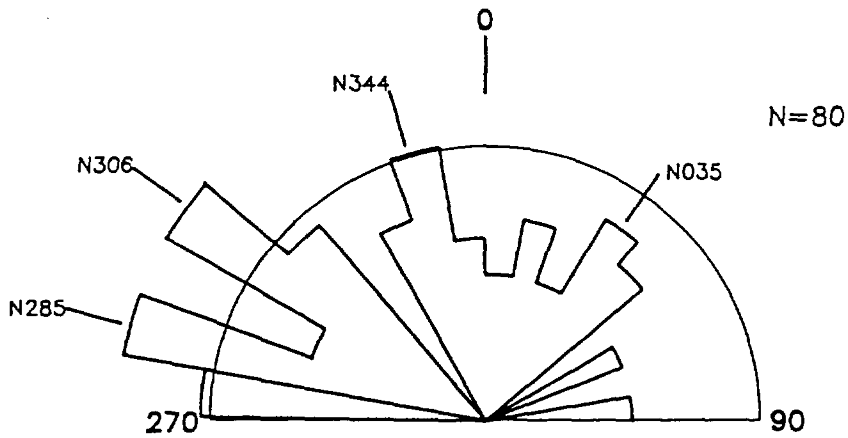


MAP STATION 13,14 N=20

Golder Associates Atlanta, Georgia			TITLE JOINT ORIENTATIONS		
CLIENT/PROJECT RESOURCE CONSULTANTS			DATE 2/7/91	SCALE N.T.S.	JOB NO. 903-3174
DRAWN GEH	CHECKED	REVIEWED	FILE NO. 903-3174	DWG. NO./REV. NO. 5	FIGURE NO. 16



HERMITAGE–CARTERS



BIGBY–CANNON

Golder Associates Atlanta, Georgia	TITLE	CUMMULATIVE JOINT ORIENTATION
CLIENT/PROJECT: RESOURCE CONSULTANTS	DATE 2/7/91	SCALE N.T.S.
JOB NO. 903–3174		
DRAWN GEH	CHECKED	REVIEWED
FILE NO. 903–3174	DWG NO./REV. NO. 4	FIGURE NO. 17

solutional and collapse features of sinkhole development. It may be speculated that the intensity, close proximity, and scattered occurrence of these sinkholes has resulted in dendritic network cave passages in the area. Such cave passages and subsurface conduits are most probably along bedding planes with local structural control by joint planes where vertical hydraulic gradients may be steep.

A similar scenario may exist beneath the Radnor Yard. Bedding control on solution features was clearly evident in the outcrops throughout the site. The Hermitage Formation is not exposed near the site, but the solution features observed along I-65 due north of the site suggest that karst development in this formation will be similar to that in the Bigby-Cannon, bedding controlled conduit systems with local effects by joint systems. In several of the boreholes and piezometer borings (P-2, BH-1, BH-8), voids in the top of the Bigby-Cannon Limestone were found, supporting the contention that karst development exists beneath the site, at least at the top of the Bigby-Cannon.

4.3.3 Hydrogeology

The site hydrogeology program included the drilling of 20 boreholes and installation of six piezometers from which geological, chemical and hydrogeological data were obtained (Figure 11). The site geology is composed of a surficial clayey silt and limestone rock fragment fill layer, overlying a clayey silt loam directly below the fill, and the Bigby-Cannon Limestone bedrock.

4.3.3.1 Fill Materials and Clayey Silt Layer

The fill layer is thinnest or non-existent in the apparent sinkhole area (BH-6) containing the diesel tank on the east portion of the site, and on the north and south sections of the site (BH-12, BH-13) where outcropping is evident. The fill layer is thickest on the west side of the site (P-4, BH-11) where the upper stream valley of Browns Creek has been filled in. The fill composition of clayey silt, rock fragments and cinder provides a very porous combination for the infiltration of precipitation.

The clayey silt loam layer, which lies between the fill and the Bigby-Cannon Limestone bedrock, has been found in nearly all the boreholes and piezometers. The clayey silt layer ranges in thickness from 3.5 feet in BH-2 and BH-9 to 32.2 feet in BH-6. The clayey silt layer becomes siltier towards the top of the bedrock.

4.3.3.2 Perched Groundwater

Perched groundwater on top of and within the clayey silt layer was observed during drilling in boreholes BH-1, BH-3, BH-3A, BH-5, BH-6, and DT-1. The groundwater levels were only measured and recorded in boreholes BH-3, BH-3A and BH-5. After blowing the boreholes dry, groundwater recovered to measurable levels in these boreholes. The other three boreholes had indications of perched zones which could not reliably be measured. The perched groundwater appears to be in isolated areas in the vicinity of the roundhouse. Its principle recharge mechanism would be infiltration of fluids from the surface. The discharge mechanism for the perched system is possibly either the storm sewer which starts at the roundhouse or the depressed area around the wastewater treatment facilities.

Three piezometers (P-5, P-6, and CSX-1) are screened in the clayey silt layer; however, P-5 was dry at the time of well construction and P-6 may be greatly influenced by a noted leaking water line. Rising head tests were performed in piezometers CSX-1 and P-6; however, the data are inconclusive because the recovery of the water levels was extremely rapid.

Comparison of the groundwater levels in the perched zone and the groundwater levels in the limestone (BH-5 and BH-5A in Table 1) indicate that the perched zone is probably hydrogeologically separated from the Limestone aquifer over most of the site. The water levels at the piezometer pair of P-2 (bedrock) and P-6 (overburden) (Table 4) do seem to track together, which suggests that there may be some connection between the limestone and the perched water at this location. Data from P-6 may not be as useful as a nearby leaking water line may have had a great impact on the water levels in P-6.

Flow within the perched groundwater system may be controlled by the structure of the top of the limestone and the clayey silt layer overlying the limestone. Since the buried stream valley is topographically lower than the surrounding bedrock and clayey silt, the perched water will tend to flow through the fill toward this valley. The subsurface drainage system runs generally from east to west and is laid generally on top of the bedrock within the buried stream valley (Figure 9). The drainage system lines are bedded in gravel, which forms a potential conduit for drainage of the perched water system.

4.3.3.3 Uppermost Aquifer

The Bigby-Cannon Limestone and Hermitage Limestone, which lies beneath the Bigby-Cannon, are the formations which form the uppermost aquifer. The groundwater capacity of the limestone formations is mainly derived from secondary permeability and porosity in the form of solution channels, joints and bedding planes. The Bigby-Cannon Limestone on site ranges in thickness from ten feet in piezometer P-4 to 31.5 feet in piezometer P-3, and is underlain by the Hermitage Formation. The large differences in thickness of the Bigby-Cannon over the site is due to erosional features, such as stream channels located beneath the western portion of the site (Figure 5).

TABLE 4

SUMMARY OF WATER LEVELS

	P-1		P-2		P-3		P-4		P-5		P-6		SS-LN-MW-6		CSX-1	
Date	W.L. (BGS) ft	W.L. Elev. (MSL)	W.L. (BGS) ft	W.L. Elev. (MSL)	W.L. (BGS) ft	W.L. Elev. (MSL)	W.L. (BGS) ft	W.L. Elev. (MSL)	W.L. (BGS) ft	W.L. Elev. (MSL)	W.L. (BGS) ft	W.L. Elev. (MSL)	W.L. (BGS) ft	W.L. Elev. (MSL)	W.L. (BGS) ft	W.L. Elev. (MSL)
12/14/90	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	13.7	571.5	23.69	575.62
12/16/90	25.23	574.97	N/A	N/A	N/A	N/A	40.15	556.45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/02/91	N/A	N/A	N/A	N/A	N/A	N/A	39.12	557.48	N/A*	N/A*	N/A	N/A	N/A	N/A	23.69	575.62
1/10/91	24.87	575.33	N/A	N/A	82.13	513.47	41.64	554.96	N/A*	N/A*	11.86	580.54	N/A	N/A	N/A	N/A
1/18/91	25.23	574.97	15.13	577.17	81.44	514.16	39.69	556.91	N/A*	N/A*	14.10	578.30	N/A	N/A	N/A	N/A
1/30/91	25.65	574.55	17.52	574.78	82.33	513.27	40.18	556.42	N/A*	N/A*	17.06	575.34	14.23	570.97	24.41	574.90
2/07/91	25.69	574.51	18.11	547.19	82.30	513.30	40.30	556.30	N/A*	N/A*	17.55	574.85	N/A	N/A	N/A	N/A
2/21/91	24.08	576.12	12.26	580.04	81.33	514.27	38.84	557.76	49.48	546.82	9.79	582.51	12.14	573.06	20.39	578.91
3/4/91	25.00	575.20	15.29	577.01	80.81	514.79	39.61	556.99	49.64	546.66	14.38	577.92	15.18	570.02	22.89	576.41

NOTE: N/A* = No water observed in piezometer.
N/A = Not available.
BGS = Below ground surface.
MSL = Mean sea level.

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Four piezometers (P-1, P-2, P-3, and P-4) are screened in limestone bedrock. Piezometer P-1 is screened in the Bigby-Cannon Limestone, whereas the other three piezometers, P-2, P-3 and P-4, are screened in the Hermitage Limestone. Three piezometers (P-1, P-2 and P-4) exhibited groundwater responses that indicate confined conditions (Table 4). The groundwater levels in these three piezometers rose rapidly, as much as 25 feet, to elevations higher than the top of bedrock elevations, after fractures were encountered during drilling. The water level in piezometer P-3, however, is extremely low, relative to the other piezometers, probably due to the lack of fractures encountered during drilling. This water level is recovering very slowly, indicating the low primary permeability of the intact limestone. A potentiometric map of the uppermost Limestone aquifer, based on water levels from P-1, P-2, P-4, and observed water levels in existing monitoring wells and select soil borings during drilling, is presented on Figure 18.

Rising head tests were performed on all four limestone piezometers and the Cooper, Bredehoeft and Papadopulos (1967) method was used to analyze the test data. Table 5 is a summary of the rising head test data and analyses. The hydraulic conductivity (K) values ranged from about 10^{-3} cm/s in P-2 (3 ft/d) to about 10^{-7} cm/s in P-3 (3×10^{-4} ft/d). The geometric mean of K values for piezometers P-1, P-2 and P-4 is 1.06×10^{-4} cm/s (0.3 ft/d). The low K value for P-3 indicates the probable lack of water-bearing fractures intersecting the borehole. The lateral hydraulic gradient from P-1 to P-4 is approximately 0.013 and from P-2 to P-4 is approximately 0.012.

The average horizontal groundwater velocity for the Bigby-Cannon/Hermitage Limestone on site, using the geometric mean K and horizontal gradient presented above, is approximately 132 feet per year. This average velocity assumes an effective porosity of 0.01 (typical of fractured rock).

TABLE 5

HYDRAULIC CONDUCTIVITY TEST SUMMARY
CSX RADNOR RAILWAY/NASHVILLE, TENNESSEE

Piezometer	Zone Screened In	Rising Head Tests Hydraulic Conductivity
P-1	Bedrock	1.84E-05 cm/sec
P-2	Bedrock	3.18E-03 cm/sec
P-3	Bedrock	5.30E-07 cm/sec
P-4	Bedrock	2.03E-05 cm/sec
P-6	Overburden	4.47E-04 cm/sec

NOTE: P-5 is dry.

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On a regional scale, the Bigby-Cannon/Hermitage groundwater system is believed to flow toward the north to northeast to the Cumberland River. However, on a site scale, local geologic structures, such as buried stream valleys and, probably, sinkholes, control the groundwater flow and direction. From the roundhouse westward toward piezometer P-4, the buried upper stream valley of Browns Creek controls the flow direction (Figure 18). The sinkhole southeast of the roundhouse, sinkholes farther east off-site, and the presence of a local groundwater divide on the eastern portion of the site, east of the Round House, may direct groundwater flow in an easterly direction. However, little groundwater data are available for the area east of the site.

Several water seeps were observed at the site. The locations of these seeps are illustrated on Figure 10. Based on field observations, the seeps are generally restricted to the northern portion of the Radnor Yard. Of all of the observed seeps, only one was discharging appreciable amounts of water at the time of observation in November 1990. This seep is located behind a building along the west side, immediately south of the oil booms on Browns Creek. Golder Associates estimated the flow to be approximately 1 to 2 gallons per minute. All of the other seeps plotted on the map were discharging negligible amounts of water at the time of observation. However, as discussed in Section 3.3.3, at other times of the year these seeps may discharge greater quantities of water, particularly in the springtime.

4.4 SUBSURFACE CONTAMINATION FINDINGS

The CAP identified the potential TRPH sources at Radnor Yard and categorized them as either point, line or area sources. These sources became the basis for selecting the Phase 1 drilling locations. The analytical results of the soil and groundwater samples collected during the subsurface investigation are described in the following sections and presented in tabular format in Appendix F. Metal concentrations determined in the soil and groundwater are shown in Table 6. Specific organic pollutants identified in the soil and groundwater samples can be found in Tables 7 and 8, respectively.

4.4.1 Borehole 1: 6-Inch Diesel Fuel Line Rupture

A 6-inch diesel fuel line which transferred fuel from the 500,000 gal storage tank to the locomotive service area ruptured in the fill area south of the locomotive shop in 1989. This line has since been replaced by a new above-ground line. Elevated TRPH concentrations were detected in the soils and groundwater at this location (see Appendix F). The highest concentration of 18,700 mg/kg occurred in the soil sample collected 7 feet from the ground surface, where water was noted. The TRPH profile is typical of the lense of contamination that occur at the groundwater surface. Metal concentrations in both the soils and groundwater were normal.

Toluene was detected (0.4 mg/l) with the semi-volatile compounds: acenapthene, bis-(2-ethylhexyl)phthalate, fluoranthene, fluorene, n-nitro-dinpropylamine, n-nitro-diphenylamine, and phenanthrene (see Table 7) in the soil sample. Some of these compounds are associated with diesel fuel contamination. All of the compounds identified are derivatives of coal-tar products, which suggests that some of the contamination may be due to cinder fill material.

Acenapthene, anthracene, fluorene, n-nitro-diphenylamine, phenanthrene and pyrene were detected in the groundwater. The concentrations of these compounds were about 20

TABLE 6

SUMMARY OF HEAVY METAL ANALYSES

Borehole/ Piezometer	Media	Antimony Sb	Arsenic As	Barium Ba	Boron B	Cadmium Cd	Chromium Cr	Copper Cu	Lead Pb	Mercury Hg	Nickel Ni	Selenium Se	Silver Ag	Zinc Zn
1	Soil	<1	1.3	289		<0.3	18	10	14	<0.1	14	1	<0.5	34
	Groundwater	<0.005	0.003	<0.1	0.29	<0.005	<0.02	<0.01	0.002	<0.0002	<0.02	<0.01	<0.01	0.02
2	Soil	<1	4.5	175		<0.5	16	9	<10	<0.1	16	<1	<1	31
	Groundwater	<0.005	<0.002	<0.1	0.45	<0.005	<0.02	<0.01	0.001	<0.0002	<0.02	<0.01	<0.01	0.01
3	Soil	<1	4.3	266		<0.3	21	13	18	<0.1	22	<1	<0.5	37
	Groundwater	<0.005	0.052	6.2	0.2	<0.005	0.45	0.32	0.93	0.0010	0.35	<0.01	<0.01	8.6
3A	Soil	<1	4.7	22		<0.3	8	446	148	<0.1	22	<1	<0.5	67
	Groundwater	<0.005	<0.002	<0.1	0.32	<0.005	<0.02	<0.01	<0.001	<0.0002	<0.02	<0.01	<0.01	0.02
4	Soil	<1	2.8	67		<0.5	<2	3	<10	<0.1	8	<1	<1	11
	Groundwater	<0.005	0.002	<0.1	0.18	<0.005	<0.02	<0.01	0.005	<0.0002	<0.02	<0.01	<0.01	0.02
5	Soil	<1	3.3	291		<0.3	18	17	34	<0.1	24	<1	<0.5	96
	Groundwater	<1	1	41		<0.5	<2	32	24	<0.05	6	<1	<1	25
5A	Soil													
	Groundwater	<0.005	<0.002	<0.1	0.19	<0.005	<0.02	<0.01	<0.001	<0.0002	<0.02	<0.01	<0.01	0.02
6	Soil	<1	0.7	162		<0.3	15	17	17	<0.1	19	<1	<0.5	35
	Groundwater	<0.005	<0.002	<0.1	0.3	<0.005	<0.02	<0.01	0.003	<0.0002	<0.02	<0.01	<0.01	0.02
7	Soil	<1	4.7	190		<0.5	18	10	28	<0.1	0.17	<1	<1	33
	Groundwater	<0.005	<0.002	<0.1	0.54	<0.005	<0.02	<0.01	<0.001	<0.0002	<0.02	<0.01	<0.01	0.02
8	Soil	2	4.8	101		<0.3	8	996	385	<0.1	25	<1	<0.5	70
	Groundwater	<0.005	0.005	0.4	0.34	<0.005	0.05	<0.01	0.032	<0.0002	<0.02	<0.01	<0.01	0.03
9	Soil													
	Groundwater	<0.005	<0.002	<0.1	0.46	<0.005	<0.02	<0.01	0.003	<0.0002	<0.02	<0.01	<0.01	0.01
10	Soil	<1	1	91		<0.3	9	5	14	<0.1	7	<1	<0.5	21
	Groundwater	<0.005	<0.002	<0.1	0.48	<0.005	<0.02	<0.01	<0.001	<0.0002	<0.02	<0.01	<0.01	0.02
11	Soil	<1	3.6	193		<0.5	12	6	<10	<0.1	13	<1	<1	21
	Groundwater	<0.005	<0.002	<0.1	0.24	<0.005	<0.02	<0.01	<0.001	<0.0002	<0.02	<0.01	<0.01	0.01
12	Soil													
	Groundwater	0.005	0.016	<0.1	4.2	<0.005	<0.02	<0.01	<0.001	<0.0002	<0.02	<0.01	<0.01	0.02
13	Soil													
	Groundwater	<0.005	<0.002	<0.1	0.35	<0.005	<0.02	<0.01	0.001	<0.0002	<0.02	<0.01	<0.01	0.02
LBH-1	Soil													
	Groundwater	<0.005	<0.002	<0.1	0.2	<0.005	<0.02	<0.01	0.003	<0.0002	<0.02	<0.01	<0.01	<0.005
DT-1	Soil													
	Groundwater	<0.005	<0.002	<0.1	0.17	<0.005	<0.02	<0.01	0.005	<0.0002	<0.02	<0.01	<0.01	0.02
P1	Soil	<1	0.8	72		<0.5	<2	3	<10	<0.1	<2	<1	<1	12
	Groundwater	<0.005	<0.002	<0.1	0.22	<0.005	<0.02	<0.01	0.001	<0.001	<0.02	<0.01	<0.01	0.01
P2	Soil	<1	1	103		<0.3	10	7	12	<0.1	9	<1	<0.5	24
	Groundwater	<0.005	<0.002	<0.1	0.085	<0.005	0.34	<0.01	0.009	<0.0002	<0.02	<0.01	<0.01	<0.005
P3	Soil													
	Groundwater	<0.005	<0.002	<0.1	0.9	<0.005	<0.02	<0.01	0.004	<0.0002	<0.02	<0.02	<0.01	0.04
P4	Soil	<1	4.4	220		<0.5	25	16	20	<0.1	12	<1	<1	46
	Groundwater	<0.005	<0.002	<0.1	0.22	<0.005	<0.02	<0.01	0.004	<0.0002	<0.02	<0.01	<0.01	0.02
P6	Soil													
	Groundwater	<0.005	<0.002	<0.1	0.14	<0.005	<0.02	<0.01	0.002	<0.0002	<0.02	<0.01	<0.01	0.02

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TABLE 7

ORGANIC POLLUTANTS IDENTIFIED IN SOILS ABOVE QL
CSX—RADNOR YARD

conc. in (mg/l)

	Parameter	BH-1	BH-2	BH-3	BH-3A	BH-6	BH-7	BH-8	BH-11	P-4
Acid Organics	4-Nitrophenol					7.6				
Base/Neutral	Acenapthene	6.3				1.1				1.2
	Bis-(2-ethylhexyl) phthalate	25	0.86	3.1		6.1			0.83	3.8
	Butyl-benzylphthalate									1.8
	Di-n-butylphthalate									1.6
	Fluoranthene	5.3								
	Fluorene	9.7				2.5	0.4			1.5
	2-Methylnapthalene					6.1				
	n-Nitro-dinpropylamine	13								
	n-Nitro-diphenylamine	13				1.3	0.47			1.8
	Phenanthrene	21				5.5	0.81			3.4
Volatiles	*Acetone					0.19				
	2-Butanone (MEK)					0.44				
	Chlorobenzene					0.2				
	4-Methyl-2-pentanone					0.15				
	Methylene Chloride							0.01		
	Toluene	0.4								
	1,1,1-Trichloroethane				0.4					
	*Xylene			0.059						

* HSL only.

TABLE 8

ORGANIC POLLUTANTS IDENTIFIED IN GROUNDWATER ABOVE QL
CSX—RADNOR YARD

Conc. in (mg/l)

	Parameter	BH-1	BH-2	BH-3	BH-3A	BH-6	BH-7	BH-8	BH-12	BH-13	DT-1	P-2	P-3	P-4	P-6
Acid Organics	4-Nitrophenol						0.32								
Base/Neutral	Acenapthene	0.25	0.078			0.16									
	Anthracene	0.11													
	Bis-2-(2-ethylhexyl)phthalate				0.1				1.4		0.012	0.048		0.35	0.094
	Di-n-butylphthalate								0.37						
	Fluorene	0.43	0.12			0.24	0.018				0.012				
	2-Methylnapthalene					0.21									
	n-Nitro-diphenylamine	0.55	0.15			0.45	0.026				0.014				
	Phenanthrene	1	0.24			0.56	0.028				0.022				
	Pyrene	0.06	0.024												
Volatiles	*Acetone														
	2-Butanone (MEK)														
	Chlorobenzene										0.02				
	Chloroform										0.02		0.01		0.03
	1,2-Dichloroethylene			0.038											
	Ethylbenzene				0.02										
	Methylene Chloride							0.01				0.02			0.02
	Toluene		0.13						0.01	0.01					
	1,1,1-Trichloroethane														
	Trichloroethylene				0.03										
	*Xylene			0.073											

* HSL only.

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times less than in the soil, demonstrating that most of these compounds preferentially absorb to soil matrices. In fact, the presence of these compounds in water collected from the borehole may be the result of solids in the water sample. A rainbow-sheen on the water surface and strong diesel odor was observed at the temporary diesel fuel recovery sump that is located about 20 feet to the north of the drilling location.

4.4.2 Borehole 2: 2-Inch Diesel Fuel Line

A 2-inch diesel fuel line serving the wreck train area ruptured in an area to the north of the turntable. Higher TRPH concentrations (46,900 mg/kg) were found in the surface soils than at Borehole 1. However, other soil TRPH concentrations were similar to borehole 1. Contamination in the surface sample and silt sample collected at 22 feet was noted by the field sampling personnel.

Groundwater was measured at 24 feet below the surface but may not have been encountered until after the bedrock was penetrated. The TRPH of this groundwater sample was 61 mg/l. The inclusion of high solids concentrations (14,200 mg/l) with adsorbed petroleum compounds is likely to be responsible for this elevated TRPH concentration.

Heavy metal concentrations were low in the soils and groundwater. Essentially the same organic pollutants were detected in the groundwater as in Borehole 1, although concentrations were less (about 25 percent of Borehole 1 concentrations). These results indicate contamination by diesel fuel and/or the influence of cinder fill.

4.4.3 Boreholes 3 and 3A: Former Lube Oil Tank Area

New and waste lube oil storage tanks and transfer pumps were located, until recently, to the east of the roundhouse. Oil was transferred between these tanks and rail cars or road vehicles. Boreholes 3 and 3A were located to the west of these facilities, adjacent to the tracks where unloading of oils occurred. Contaminants identified here could reflect oil releases from the tanks or previous oil transfer operations. This area may also have been affected by the migration of contaminants from neighboring properties.

Retrieval of soil samples from Borehole 3 was extremely difficult due to the composition and nature of the fill material under the railway tracks at this location. TRPH concentrations of 840 mg/kg were found in soils at 25 feet, which corresponded to a perched groundwater level. The TRPH concentration in the groundwater was 73 mg/l. The groundwater sample had elevated concentrations of arsenic, barium, chromium, copper, mercury, nickel, lead and zinc. This is attributed to the suspended solids (soils) included with this water sample as well as the potential presence of waste oil.

Borehole 3A was drilled on the south side of the track pans at the lube oil transfer area to obtain additional soil samples. Soil TRPH concentrations were between 8,400 and 15,000 mg/kg between 10 and 20 feet. They quickly decreased to background concentrations (< 20 mg/kg) after the groundwater was encountered. TRPH in the groundwater was 30 mg/l. While TRPH concentrations were higher than at borehole 3, metal concentrations were below detection limits.

In contrast to boreholes 1 and 2, the only organic compounds detected in the groundwater at these two locations were volatile compounds with only one exception [bis-(2-ethylhexyl)phthalate in borehole 3A at 0.10 mg/l]. Low levels of 1,2-dichloroethylene, ethylbenzene, toluene and xylene were detected in the groundwater. Xylene and 1,1,1-trichloroethane were also detected in soil samples collected from boreholes 3 and 3A, respectively.

It appears from these results that the soils and perched groundwater at this location could be affected by all of the suspected sources. The presence of volatile organics that are not associated with railroad operations suggests that some migration of contamination from an adjacent site may have occurred.

4.4.4 Borehole 4: East of Locomotive Shop Area

Borehole 4 was drilled in the area west of the locomotive shop. Used oil filters are disposed into a roll-off bin near the roundhouse for recycling. There was formerly a press to extract oil from the old filters. Oil stains and deterioration was observed at the asphalt surface.

TRPH concentrations were very uniform throughout the top 25 feet of fill, ranging between 975 and 1,750 mg/kg. The TRPH concentrations dropped to background levels (20 to 120 mg/kg) at depths below 26 feet. This corresponds approximately to the bottom of the fill material overlaying the natural silt layer.

The groundwater level was recorded at 21 feet. The TRPH concentration of the groundwater was 410 mg/l but the sample included 1,000 mg/l of suspended solids which probably affected the results. The high TRPH concentration in the groundwater sample and the low TRPH concentrations in the soils below 26 feet suggest that the perched groundwater may extend to this area or that subsurface drainage is occurring. However, a perched groundwater was not observed at the time of drilling. Metal concentrations were at detection limits and no organic pollutants were detected.

These results indicate that the TRPH concentrations here are probably more related to oil than diesel fuel. As this location is away from locomotive traffic areas (mainly road vehicles) the almost uniform TRPH concentrations throughout the fill suggest that leakage from the bin(s) and prior equipment used in the disposal of lube oil filters and fuel filters has caused extensive contamination of the underlying soils.

4.4.5 Boreholes 5, 5A, LBH-1, LBH-2 & LBH-3: Roundhouse Area

Boreholes 5 and 5A were drilled within the inner circle of the roundhouse. Ballast between the tracks shows oil contamination due to oil leakage from locomotives entering and leaving the roundhouse. Locomotives have at times ruptured their fuel tanks when they have derailed into the turntable pit.

TRPH concentrations of soil samples taken from Borehole 5 showed contamination only extended to a four to seven-foot depth below the surface. The TRPH concentrations then increased at the groundwater level, about 20 feet below the surface. TRPH concentrations in the groundwater was high, at 750 mg/l, but this sample also contained a large amount of solid material (20 percent). The high solids content also had a severe impact on the metal concentrations in this sample, and more accurately reflects the metal concentrations in the soils. Despite the high TRPH levels, no hazardous substance list (HSL) pollutants were detected in the soils.

Borehole 5A was drilled next to Borehole 5. The drillers drilled to bedrock, cased and blew out the hole to remove contamination due to the overlying fill. Drilling was then continued into bedrock. The groundwater sample collected from borehole 5A therefore originated from the bedrock aquifer. The TRPH concentration of this sample was 0.2 mg/l. Metal concentrations in the groundwater were at detection limits. No organic pollutants were detected in this sample.

The results indicate oil/weathered fuel contamination exist near the groundwater/soil/fill interface underlying the roundhouse. A very shallow, perched groundwater was identified. The aquifer within the bedrock does not appear to be impacted.

Additional boreholes were drilled at the location of the new lube oil storage area. The purpose of these boreholes was to obtain information for the design of the new containment area foundations and ensure that this area was not contaminated. Apart from some surface contamination, all other fill material at this location was clean. The borehole revealed a lot of cinder fill, and voids were encountered within the bedrock. Groundwater was recorded at between 25 and 28 feet, and probably came from within the bedrock. No TRPH were detected in the groundwater at this location.

4.4.6 Boreholes 6, DT-1 and DT-1A: Diesel Storage Tank

Borehole 6 is located on the southeastern corner of the containment berm which surrounds the large diesel fuel storage tank. Investigations in this area were supplemented by additional boreholes DT-1 and DT-1A located inside the containment area to the east of the storage tank.

TRPH concentrations in the soil samples increased from 460 mg/kg five feet below the surface to 5,500 mg/kg at a 15 to 20 foot depth where a perched groundwater was encountered. TRPH concentrations then decreased to background levels at about 25 feet. The TRPH concentration in the groundwater was 410 mg/l. Metal concentrations in the soils and groundwater appear normal.

Two additional boreholes (DT-1 and DT-1A) were drilled to investigate the soils inside the containment berm. Soil samples had a diesel odor and analyses revealed a contamination layer typical of fuel floating on top of groundwater. However, no floating, free-product was detected. The highest soil TRPH concentration was 46,200 mg/kg (essentially, saturation) at a 12-foot depth. The corresponding groundwater concentration was 80 mg/l.

Tables 7 and 8 show that the semi-volatile substances detected in both BH-6 and DT-1 are similar to those found in boreholes 1 and 2, and are probably indicative of diesel fuel contamination. Some evidence of spilled or leaking diesel can be seen within the containment area adjacent to the tank. It is interesting to note that the groundwater concentrations of semi-volatile compounds are at least 20 times greater at BH-6 than DT-1, opposite to the trend that would be expected if the diesel tank was the source of these semi-volatiles. Also, the volatile compounds detected in the BH-6 soil sample (acetone, MEK and chlorobenzene) are not diesel fuel constituents. It is possible that this location is being impacted by off-site contamination. Chloroform and dichlorobenzene were detected in the groundwater at low concentrations at DT-1.

4.4.7 Borehole 7: Locomotive Servicing Area

Borehole 7 was located to the southwest of the locomotive shop, and north of the refueling apron. Soils and groundwater in this location may also have been influenced by the 6-inch diesel fuel line rupture (see Borehole 1).

A high TRPH value (5,920 mg/l) was found in the surface material but concentrations quickly dropped to background levels until a depth of about 23 feet. The soil TRPH concentration at this elevation was 1,000 mg/kg. It is believed that groundwater was not encountered until the bedrock was penetrated at this location, although it was later measured at 24 feet. The groundwater TRPH was 8 mg/l and had a suspended solids concentration of 41,300 mg/l. The solids could easily account for the observed TRPH concentration. The soil TRPH profile does, however, indicate that some surface-to-subsurface drainage is probably occurring intermittently at this location.

As at other boreholes, the metal concentrations were at background levels in both the soil and groundwater samples tested. The organic compounds detected at borehole 7 were similar to the other locations where diesel contamination is suspected. No volatile compounds were detected. There was one anomaly, however, at this location. Nitrophenol (an acid semi-volatile, which is not very soluble in water) was detected in the groundwater at 0.32 mg/l. This was the only occurrence of this compound in the groundwater during this project, and it may be associated with the high suspended solids (soil/cinders) in the water sample.

Due to the lower organic compound concentrations found and the apparently clean fill material between the surface and the groundwater, it is likely that groundwater contamination at this location could be due to the 6-inch diesel fuel line rupture.

4.4.8 Borehole 8: West of Car Shop Area

Borehole 8 is located to the east of the car shop repair area adjacent to a ready track. There is evidence of oil leakage on the ground at this location. This is in the vicinity of the main storm sewers which drain the roundhouse area.

Soil sample analyses show TRPH contamination within the top seven feet of fill and at the groundwater level, with clean soils being detected both above and below the groundwater. Although the TRPH concentration in the soils at the 23 to 25-foot depth was high (29,000 mg/kg), the TRPH concentration in the groundwater was only 0.4 mg/l. Suspended solids were measured at 30,900 mg/l. The Golder hydrogeologist reported that water was not encountered until the bedrock was penetrated. This groundwater quality therefore represents the groundwater in the limestone aquifer. This conclusion is supported in that the priority pollutant scan detected no organics except for low levels of methylene chloride (0.01 ppm) in both the soil and groundwater samples; and the detection of methylene chloride has been attributed to contamination within the laboratory.

While no perched groundwater or subsurface drainage was identified at the time of the investigation, the TRPH concentration profile indicates that there is probably intermittent storage of water within the fill at this location.

4.4.9 Borehole 9: Load Test Platform

Borehole 9 is adjacent to the "load test" platform located on the ready tracks north of the roundhouse. Lube oil and fuel leaks, along with coolant leaks from locomotives can occur in this area, as the locomotive engines are test-run at load. Slight contamination of the ballast is apparent at this location, due to locomotive traffic. No contamination was detected in samples collected between the surface and a 23-foot depth. The TRPH concentration increased to 120 mg/kg at this depth. This lower level corresponds to the organic silt layer that overlays the Bigby-Cannon limestone formation.

Groundwater was not encountered until after bedrock was penetrated, after which it rose to a 22-foot depth below the surface. The TRPH concentration in the groundwater was less than the detection limit of 0.1 mg/l. Metal and suspended solids concentrations were also below detection limits in the groundwater. No organic pollutants were detected in either the soil or groundwater samples. All of this information confirms that the water quality of the aquifer has not been impacted.

4.4.10 Borehole 10: Oil Recovery Lift Station

Borehole 10 was sited next to the oil recovery manhole located due west of the car shop maintenance area on the road which runs along the eastern side of the classification yard. Storm water from the roundhouse area sewer drains to this point. The objective of drilling this borehole was to determine whether storm water was migrating along the storm sewer trench outside the sewer pipe.

Apart from a soil sample with a TRPH concentration of 270 mg/kg collected at a 12-foot depth, no other TRPH were detected in the soils. No perched groundwater was encountered. The groundwater level rose to 18 feet below the surface after the limestone bedrock had been penetrated.

The TRPH concentration in the groundwater sample was 0.2 mg/kg. Metal concentrations were also at background levels. No organic priority pollutants were detected in either the groundwater or the soil samples.

No evidence was found that suggested that a significant amount of contaminated subsurface drainage is migrating along the outside of the storm water sewer pipe.

4.4.11 Borehole 11: Storm Water Sewer West of Classification Yard

Borehole 11 is on the west side of the classification yard and adjacent to the storm water sewer line which runs between the oil recovery manhole and the junction manhole. This location was selected to provide information on the nature of the fill material under the classification yard area, and to seek additional information regarding the movement of subsurface drainage along the storm sewer trench.

All seven soil samples collected at this location had TRPH concentrations less than the detection limit of 20 mg/kg TRPH. A groundwater sample was collected after it stabilized at 24 feet. The Golder hydrogeologist reported that the groundwater was not encountered until after the bedrock was penetrated at 52 feet. TRPH in the groundwater was also less than the detection limit of 0.1 mg/l. Metals concentrations in both the soil and groundwater samples were also low. Bis(2-ethylhexyl)phthalate, was the only organic priority pollutant identified. It is, like methylene chloride, a common laboratory contaminant.

Gravel and rock fragments were detected in the fill during drilling which would indicate the borehole was near the main storm water line between the oil recovery manhole and the sewer junction manhole. It is also interesting to note that the top of the silt layer was higher at this location than at Borehole 10. This would indicate that subsurface drainage would probably travel in a more southerly direction before turning to the north, following the in-filled valley.

4.4.12 Borehole 12: Air Compressor for Retarders and Associated Oil Separator

This borehole is located at the southern end of the classification yard on the west side of the hump track. It is adjacent to a building which houses an air compressor for the rail car retarders and also an oil skimmer. Bedrock was struck immediately below the gravel surface and no soil samples were collected. Drilling proceeded to a depth of 55 feet. The interface between the Bigby-Cannon and the Hermitage formations was estimated at approximately 30 feet.

Groundwater was measured at 35 feet, and analyses showed less than detectable amounts for TRPH and metals. Toluene was measured at the detection level. Bis-(2-ethylhexyl)phthalate and di-n-butylphthalate were detected in the groundwater sample at

1.4 and 0.37 mg/l. The recurring detection of these compounds on this project has been attributed to the use of PVC screens and risers. The use of phthalates as plasticizers for PVC products has been well documented and the occurrence of these compounds has been observed during other site investigations.

4.4.13 Borehole 13: Piggy-Back Crane Area

This borehole is adjacent to the piggyback crane repair area. A containment area and oil storage structure have been constructed to capture released oils. The borehole was located next to an oil collection sump which had visible, above-grade oil leaks from joints in this structure.

As with Borehole 12, bedrock was encountered at the surface. No TRPHs were detected in the overlying soil/gravel material. Heavy TRPH contamination (3,270 mg/l) of the groundwater was encountered, at only four feet below the surface. All other parameters were at, or below, detection limits. The contamination is obviously due to the oil leaking from the adjacent sump.

The extremely shallow depth of the groundwater, 4.3 feet, was initially thought to be an anomaly at this location. A company which specializes in finding underground leaks from water lines surveyed the area but could not find any leaks in this area. Water has been observed in the drainage ditch about 50 yards to the north of this location. Although unlikely, this could represent a local spring within the Bigby-Cannon formation when water levels are high. The possibility of water leaks in the fire water supply line has not yet been ruled out.

4.4.14 Piezometer P-1: North Car Shop Area

In addition to the boreholes described above, piezometers were installed as part of the subsurface investigation to help determine the site geological and hydrogeological characteristics. Soil samples were collected during the drilling and analyzed for the same parameters as the boreholes above. Piezometer P-1 is located on the west side of the car shop area at the top of the embankment, approximately 400 feet north of the oil recovery manhole. The purpose of this piezometer was to establish the groundwater conditions on the northern side of the suspected area of contamination.

No contamination was suspected at this location and none was found in either the soil or groundwater samples. Groundwater was encountered after the limestone bedrock had been penetrated. The groundwater rose and stabilized at a level of 25 feet below ground elevation. This elevation corresponded to the interface of the fill material and silt layer which overlays the bedrock.

4.4.15 Piezometers 2 and 6: Southeast of Classification Yard

These piezometers are located on the southeast side of the classification yard. P-2 is a deep piezometer with the screen set in the limestone bedrock. P-6 is a shallow piezometer set above the limestone. There are no facility operations in this area which could result in either soil or groundwater contamination.

It was difficult to determine the level at which groundwater was first detected at these locations. However, it was measured at about 12 feet after it had stabilized. Low levels of phthalates and methylene chloride were found in the groundwater samples but not in the soil samples. Chloroform was also detected in the groundwater sample from P-6.

The only explanation that can currently be offered for the presence of these compounds is contamination in the laboratory.

4.4.16 Piezometer 3: West Side Classification Yard

This piezometer is located in the middle of the TOFC area to the west of the classification yard, and is directly under a power transmission tower. All analyses of the soil samples revealed low TRPH values with the exception of the sample collected at a depth about 22 feet, which had a TRPH concentration of 350 mg/kg. This soil may represent contaminated fill material hauled in during the TOFC area construction. The elevation of the original surface was observed about five feet below this sample.

The Bigby-Cannon and Hermitage formations were struck at approximately 33 and 65 feet, respectively. Groundwater was not detected until the borehole reached over 85 feet. The well was advanced to 95 feet and the groundwater slowly recovered to a level 83 feet below the surface, indicating a very tight formation. Chlorobenzene was the only priority pollutant identified. It was barely detected at 0.01 mg/l, which may represent laboratory contamination.

4.4.17 Piezometer 4 and 5: Sewer Junction Manhole

These piezometers are adjacent to the storm sewer junction manhole located in the northwestern area of the TOFC area. Contamination in this area could indicate subsurface drainage along the storm sewer trenches but more likely reflects contamination of the area around the former oil separator system located here before the TOFC area was developed.

Piezometer P-4 is screened within the bedrock while P-5 is screened in the overlaying fill material. Soil samples taken from the P-4 borehole showed no significant TRPH contamination until a depth of about 48 feet was reached. TRPH concentration in the soil was measured at 3,000 mg/kg. Phthalates and some of the other non-volatile parameters identified in boreholes BH-1, BH-2, BH-6 and BH-7 were also detected, indicating some probable diesel contamination. The 48-foot depth corresponds to the top of the storm water sewer and is located in the middle of the stiff, dark brown clay which was found to overlay the limestone bedrock which occurred at approximately 58 feet. The Hermitage formation was encountered at 68 feet.

Water is believed to have entered the borehole below bedrock but quickly rose to 40 feet below the surface. This elevation corresponds to the top of the silt layer overlaying the bedrock. The quality of the groundwater at this location was good, with non-detectable TRPH and metal concentrations. Bis(2-ethylhexyl)phthalate was once again identified in the groundwater sample.

The purpose of P-5, the shallow piezometer, was to enable monitoring and sampling of subsurface drainage that may be travelling outside the sewer pipe and migrating off-site. P-5 was located midway between P-4 and the storm water junction manhole and was drilled to bedrock (approximately 58 feet). Due to the near proximity of the storm sewer line, the silt layer overlaying the bedrock was not encountered. Soil samples were not collected for TRPH analysis; however, diesel or oil contamination was not observed in any of the three samples collected between depths of 40 and 50 feet. Limestone gravel was encountered between 48 and 58 feet, indicating that the piezometer was located within the sewer trench. Difficulties in establishing the screen resulted in the finished piezometer only going down to a depth of 50 feet. No significant water levels have been measured in this piezometer.

4.5 IDENTIFICATION AND ASSESSMENT OF SURFACE CONTAMINATION SOURCES

There are extensive areas around the roundhouse and locomotive shop that do not have track pans and show heavy surface contamination, primarily by leaked oil from the locomotives. Preliminary investigations were performed to determine whether this surface contamination of ballast material represented a significant source of contamination to the underlying soils and groundwater.

Inspections were made around the roundhouse and locomotive shop to confirm the extent of track pan coverage, note areas where track pans were damaged, and define areas where oil contamination existed on areas without track pans. These locations have been mapped and are shown on Figure 19.

In addition to the inspections, contaminated ballast was removed by shovel to determine the depth that the heavy oil had permeated. Samples were also collected of the most heavily contaminated ballast and soils. The following observations were made:

1. In general, most of the oil contamination on the ballast in these areas remained near the surface. The presence of traction sand appeared to help adsorb the oils. In many of the locations examined, visible contamination stopped within a foot of the surface.

2. The most heavily contaminated areas were located next to damaged track pans. Three samples collected at a one-foot depth had TRPH concentrations of 7,100, 1,980 and 10,600 mg/kg. Contamination extended to a greater depth in these areas. The actual depth could not be determined due to the difficulties in digging in the ballast material.

<u>OVERSIZED</u>

<u>DOCUMENT</u>

1

It would appear, for the most part, that the oily contamination is limited to the top one or two feet of surface material. TRPH levels may extend deeper where oils saturate the surface and insufficient surface area is available to adsorb the oils. Rainfall which falls in the areas without track pans is not expected to dissolve high levels of TRPH due to the limited solubility of these heavier oil products. However, migration could be enhanced if significant amounts of diesel fuels, which act as a solvent, are released in these areas. Rainfall could then wash these fuel solubilized compounds to greater depths.

All of the tracks entering and leaving the diesel refuelling area are panned, although leakage from overflows of locomotives may occur after they have moved away from this area. It is important that the track pans are kept repaired and well maintained. Additional pans may need to be installed at heavily contaminated areas.

4.6 ASSESSMENT OF FREE-OIL WASTEWATER TREATMENT FACILITIES

The equipment and operations at the free-oil wastewater treatment facilities were evaluated because any problems associated with this system could impact the quality of the storm water discharge from the site. In particular, excess flow from the oil recovery lift station is known to limit the capacity of the flow equalization lagoon. Improvement and expansion of this system are alternatives for reducing TRPH discharges to Browns Creek.

The headworks system was not designed to remove smaller particulate material. This material, which can include a substantial amount of adsorbed TRPH, is carried into the second (concrete lined) lagoon where it settles. Over the period that the plant has operated, a significant amount of sediment has built-up. Storm water runoff has also carried some soil into the basin on the south side. The depths of accumulated sediment were measured, and samples collected for TRPH analyses. The sediment depth had an average depth of 1 foot. This represents an approximate volume of sediment of 300 cubic yards. Results of the gravimetric TRPH analyses for the sediment were 126,000, 29,800, 48,800 and 22,400 mg/kg. Oils can be released from this material and progress further through the treatment system.

Oil scum has been observed on the surface of the large, surge lagoon with the location being dependent on the prevailing wind direction. Tears in the liner can be seen in both northern corners at the lagoon. In general, the level of the lagoon is generally too high to provide much surge protection. This may be due to the volume currently being pumped from the oil recovery lift station, or hydraulic capacity limitations of the vertical tube coallescer (VTC) unit. In addition, the oil skimmer on the overflow from the sludge lagoon is inadequate to prevent oil on the surface from discharging. This overflow eventually flows into the storm sewer.

The tube pack in the VTC has been removed which has reduced the function of this unit to a simple oil skimming device. This change has substantially reduced the efficiency of oil removal. The tube unit should be reinstalled as soon as possible or a larger simple API unit should be installed in its place.

An analysis of the pumps and force main to the city sewer indicate that the system has a 550 gpm capacity.

In the event that the pump station to the sanitary sewer is inoperable, effluent from the free-oil facility overflows into the storm sewer. Operators will not necessarily be alerted to the fact that an overflow is occurring if the overflow is due to a pump electrical failure because the existing alarm (which is worn out) is powered off the same electrical source as the pumps. This weakness was demonstrated during a diesel release that occurred in November, 1990. Luckily, the oil recovery lift station recovered much of the lost diesel fuel.

It is recommended that an independent, new alarm with flashing light, served by a second electrical source, be installed to correct this problem.

Finally, the oil recovery manhole and lift station have been reviewed. It was determined that the system has problems functioning during periods of rain. Turbulence caused by the additional flow in the pipe, storm water entering via a vertical line just upstream of the manhole, and storm water cascading down from the road surface mixes and emulsifies oils which can then pass under the baffle. Grit and sludge, which also carries TRPH products, were noted to accumulate at the bottom of the manhole pit and provided another transport mechanism of oils through the system. Diesel fuels, which mix better with water than lube oils, were also observed to pass under the baffle. Measurements of the manhole showed that the manhole connection to the lift station was not constructed exactly as designed, which may also reduce the unit's effectiveness.

5.0 POTENTIAL ALTERNATIVE REMEDIAL MEASURES

Alternative remedial measures are being developed to reduce the amount of petroleum products leaving the Radnor Yard site. Budget costs will be assigned to assist with the evaluation of each alternative. In this section, a brief summary of the suspected sources and migration routes of TRPH from Radnor Yard to Browns Creek is presented. Based on this present understanding of the problem, remedial strategies and alternatives are presented.

5.1 SUMMARY OF CONTAMINANT SOURCES AND MIGRATION PATHWAYS

Physical inspections of the roundhouse storm sewer and oil recovery manhole, and the results of water samples collected at these locations suggest that this sewer is the only definable source of TRPHs emanating from Radnor Yard. This sewer carries a significant flow of water, even during dry periods, which indicates that the sewer is providing subsurface drainage of the fill around the roundhouse and car shop area, or that there may exist some crossed sewer connections. Results from the interim monitoring program do not suggest that there are any sanitary wastewaters in this line. The amount of flow observed in this pipe during a prolonged period without rainfall suggest that leaks from the water supply system may exist.

It was apparent when the investigators entered the baffled oil recovery manhole that this flow is carrying significant amounts of petroleum products. The oil-water mixture in the adjacent lift station also has a strong petroleum odor, and the pumped discharge from this unit into the free-oil system indicates that the oil recovery system is recycling the majority of oils entering the manhole. Visual observations reveal that a some of the TRPH products and oils adsorbed to sediments (which settle and accumulate in the bottom of the manhole) probably pass through to some degree. However, the results of the interim monitoring program indicate that this unit can function reasonably during dry-weather periods.

Observations of the discharge to Browns Creek and the oil recovery manhole show that TRPH concentrations increase during and after storm events. Turbulence in the oil recovery manhole created by the higher sewer flows and surface drainage falling 30 feet into the manhole agitate the hydrocarbons and water to the point where they can pass under the baffle.

There are a number of potential TRPH sources that could discharge or infiltrate into the storm sewer system. Subsurface investigations have revealed a number of contaminated areas in the vicinity of the roundhouse and the wastewater treatment facilities. The sewer investigation, although only a portion of the pipe was able to be inspected, revealed a number of joint displacements and leaks. The contamination observed in soil samples collected from the service track area (BH-7 and BH-8), immediately west and south of the roundhouse, indicated subsurface drainage to the storm sewer is probably occurring. However, given that the hydrocarbons in the soils will generally float on the surface of water and that the size of the cracks in the pipes were small (although possibly numerous), the opportunity for TRPH compounds to find their way into the sewer seems limited. In addition, TRPH products continued to be present in the storm sewer discharge even during periods when drilling indicated that no subsurface drainage or perched groundwater was present. This finding indicates that there is a persistent source of TRPH products that seems unrelated to the subsurface contamination in the area.

A TRPH-contaminated perched groundwater system was observed in the area near the former lube oil tanks and to the south near the diesel tank. Based on the available information, it is postulated that subsurface drainage is occurring on the eastern side of the site via two possible drainage routes—towards the storm sewer or into the sinkhole/

depressed area where the wastewater treatment facilities are located. Both routes could be active and the area(s) to which they discharge have not yet been distinguished.

The results of the boreholes next to the oil-recovery manhole and west of the classification yard indicate that any storm water which drains outside the sewer pipes, if it follows this route, is not contaminated. This may be due to TRPH compounds absorbing to soil materials in the fill which underlies most of the site. The speculation that TRPH does not travel extensively through soil media is supported by the observations made during sampling the most heavily contaminated surface areas. The contamination was generally limited to the first foot of ballast material.

In addition to the subsurface contamination, there are a number of other potential sources that could be contributing TRPH to the sewer, particularly during wet weather. These sources include the overflow from the surge lagoon, and inadequate containment structures for many of the tanks storing petroleum products.

5.2 ALTERNATIVE REMEDIAL MEASURES UNDER CONSIDERATION

Based on the findings discussed above, a variety of alternative corrective measures have been developed to reduce the TRPH from leaving the CSXT property and are presently being evaluated. These alternatives focus on achieving the following goals:

1. Improved TRPH removal is required from the flow in the storm sewer serving the roundhouse and eastern side of the site.

2. The alternatives selected for improving the discharge quality should not diminish the performance of the existing free-oil treatment system. If possible, the reliance on the free-oil treatment facilities to treat the storm water flow should be

relegated to a back-up system only. The capacity of the free-oil system needs to be re-evaluated based on the selected remedial alternatives to minimize overflows into the storm sewer in the future.

3. Correction of the identified TRPH sources needs to be pursued to prevent continuing discharges in the future.

The following alternatives are under evaluation for providing improved treatment of the roundhouse storm sewer flow.

5.2.1 Treatment of Roundhouse Storm Sewer Flow

A phased construction approach is planned to improve the water quality discharge from the Radnor Yard site. The first phase would involve modifications to the oil recovery manhole. Essentially, the structure would be modified to achieve the following objectives:

1. Turbulence in the manhole will be reduced to minimize petroleum products bypassing the baffle. Road drainage will be rerouted into the manhole on the downstream side of the baffle.

2. The manhole will also be modified to incorporate a gate on the south side of the structure which will eventually be used to divert flows up to 1,000 gpm for treatment. A new valve arrangement will be installed to control flow between the existing manhole and the existing lift station.

The reduced turbulence in the manhole and improved control of recycled flow to the free-oil facilities can be implemented fairly quickly and should produce some immediate benefits. This manhole (or its equivalent) must be maintained in the system to allow routing of peak storm flows to Browns Creek.

In Phase 2, additional treatment capacity for the 1,000 gpm flow would be installed. The structures envisaged at this time include an enclosed screw pump and API separator. Additional treatment units may be necessary depending on the level of treatment required. The feasibility of accommodating such facilities next to the road and on the south side of the oil recovery manhole is under review.

A preliminary design flow of 1,000 gpm has been established. After treatment, the flow would return to the downstream side of the baffled manhole.

5.2.2 Treatment of Total Discharge to Browns Creek

Treatment of the entire flow is a consideration. Options for treating the entire collected flow at Radnor Yard are limited to two areas: the TOFC area and the existing discharge point west of the Sidco/Powell intersection. Finding space in the TOFC area that would not interfere with daily operations could present a problem. More importantly, flow would have to be lifted over 50 feet, which is a difficult and expensive proposition for screw pumps. Screw pumps are considered necessary because they will minimize the emulsification of oil.

An alternative site for treatment facilities is on the Oman estate property near the existing discharge. Access to the stream flow is not a problem here, but, since the land is not owned by CSXT, some agreement with the Oman estate would be necessary before the project could proceed. This could severely impact the schedule for compliance.

Provision of treatment facilities for the entire creek flow would be an order of magnitude more expensive than the facilities proposed for the oil recovery manhole due to the increase in design flow. A substantial portion of that flow comes from upstream of the CSXT property, or from the classification yard sewer which has been shown to be clean.

The construction of new facilities at the oil recovery manhole should provide a substantial improvement in the amount of TRPH compounds discharged from the CSXT site. The extent of this improvement can be determined after the treatment facilities at the oil recovery system have been completed. If it is found that additional treatment is required for the storm water drainage from areas other than the roundhouse sewer flow, a permanent structure for flow skimming should then be constructed in the TOFC area or at the stream discharge point.

5.2.3 Correction of Wastewater Treatment Facility Deficiencies

The existing free-oil facilities should be cleaned, repaired, refurbished, replaced, and expanded as necessary to handle the increased flows which occur during storm events. As the existing oil recovery system will continue to be operational and act as a backup system if the new proposed facilities are taken off-line for maintenance, improvements in this system are required to maintain treatment integrity.

Specifically, the oil belt skimmers and grit removal unit should be well maintained and the sludge in the upper pond needs to be periodically removed. The liner in the surge lagoon needs replacing, and an improved oil retention device installed at the overflow point.

A new tube-pack in the vertical tube coallescer (VTC) unit is necessary to reduce the TRPH levels in the free-oil effluent discharge to the Metro sewer. Adding another VTC (or similar unit) will also be necessary to handle the additional flow. An independent alarm should be installed at Metro sewer pump station to alert workers when free-oil discharges are bypassing the pump station and flowing into the storm sewer.

A better containment structure should be built for the traction sand beds north of the emulsified oil treatment building. In addition, oil from around the north free-oil separator should be regularly removed and the containment structure assessed, and repaired as necessary, to prevent any leaks.

5.2.4 Correction of Potential TRPH Sources

Design is about to begin for new diesel fuel storage tanks and a new concrete containment structure.

A concrete bottom and new drainage sump should be installed in the turntable pit and the existing drain line blocked to prevent diesel fuel spills into the storm sewer. Captured flow should be piped to a new lift station nearby which would also receive the flow from the old collector sewer circling the west wall of the roundhouse. The lift station would pump the oily waters to the free-oil treatment system.

A new system is recommended for handling used lube oil filter and fuel filter cartridges. The new system should include a containment structure.

Construction of a new main lube oil storage and containment structure was almost complete at the time this report was prepared. Other oil storage tanks on the site also require improved containment structures, such as the one containing several tanks located to the south of the locomotive shop and the sump near the piggyback crane area. A former lube oil tank on the south side of the car shop area has already been removed; the underground oil line connecting it to the roundhouse was a suspected leaking oil source.

Damaged track-pans and cross drains need to be repaired or replaced, and the area of track-pan coverage expanded to include areas where the most heavily contaminated ballast exists. A regular schedule for cleaning the industrial sewers should be implemented. After the initial cleaning, the sewers should be televised or tested to the extent possible to determine that pipes are intact.

Temporary improvements may be appropriate either at the mouth of the main storm sewer or at access points (manholes) within the sewer to improve oil boom (containment and sorbant) anchorage and performance.

6.0 RECOMMENDATIONS FOR PHASE II INVESTIGATION

Additional investigations are recommended at the Radnor Yard site to provide information on the following three areas:

1. Investigation of the hydrogeology in the overburden and upper limestone in the roundhouse area is recommended to further assess groundwater movement and contamination migration in this area. Phase I investigations revealed a contaminated perched groundwater and areas of subsurface drainage around the roundhouse. The underlying aquifer was not found to be impacted; however, as this location appears to be directly on a groundwater divide, contamination could be travelling off the CSXT property in an eastern direction.

2. Additional investigations are required in the areas where heavy subsurface contamination was found. Such investigations will define the extent of contamination and determine whether remediation of these soils is necessary. The ability of the soil in the fill and regolith to retard diesel and oil movement should be determined.

3. A bedrock well near Browns Creek should be installed to confirm that contamination is not migrating off site in that direction and mixing in the uppermost aquifer; and

4. A better understanding of the site hydrology is required, with particular attention paid to surface and subsurface drainage pathways, the subsurface storage potential, and the potential impacts of leaking water supply systems on the migration of TRPH around the roundhouse area. If infiltration into the storm sewers is minimized, less TRPH will be introduced from sources indirectly

connected to the storm sewer system. Renovation of the existing roundhouse sewer may be necessary. Preliminary estimates of design flows for the proposed expansion of the free-oil treatment system must be confirmed and the design must be finalized.

5. Flows through the roundhouse storm sewer should, if possible, be minimized. A reduction in flow will improve the efficiency of the existing oil recovery system and potentially reduce the amount of TRPH substances being carried by this sewer. Flow reductions could be potentially achieved by:

   - finding and eliminating leaks in the water supply system;
   - finding and eliminating leaks in the industrial sewers;
   - finding and eliminating potential cross connections of sewers;
   - installing a new storm water sewer to carry clean storm water from building roofs and clean pavement areas, which would convey the clean storm waters around the existing storm water sewer system.

APPENDIX A

GEOLOGIC MAPPING NOTES

RESOURCE CONSULTANTS

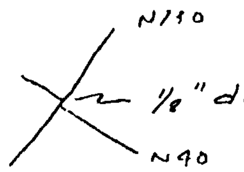
Subject 903-6319 Date 11/6/90 By R. Venkatakrishnan R.L. Koth

Map Sta

*All intervals are in single (3') paces.

1 Bigby-Canyon
Joint orientation N130
reg set, 24" spacing,

N40



Near underpass, fossil hash (non-dif)

2 Beneath RR underpass

Prob Uppermost Bigby-Canon
sel silicification of fossils,
- Med-coarse grd, bioclastic lst
si fossils, minor cross strat. med to coars grd
- fine to med grd, thinly sst w/
calcareous cement, interbedded

Karstification, solution rounding &
scalloping, bedding // spring flushing

Disrupted bedding, i.e. N dip, S dips
indicative of collapse feature

Joint N120, solution widened @
btm, penetrative throughout outcrop
jagged, irregular.

Subject 903-6319 Date 11/6/90 By R. Koth R. Venkatakrishnan

Map Sta

3 10' below #1

- fine-grd, dove gray, microcrystalline,
med-bedded, lime mudstone,
showing effects of surface karst -
pit marks, runnel karst
interbedded w/, modestly fossiliferous, intra
Clastic rip → med-grd, thin bedded, sandstone/ siltstone

gentle ~~west~~ (NE) dip (~3 to 5 deg)

Joint Orientations
N345 }
N343 } closely spaced, ~6 to 8"
N340 }

N216

Joints are solution enlarged, up to
3.5" in depth

~20' below #1 ~ seep level

massive bedded (to med), dove gray lime
mud w/ occasional, calcareous shale
interbed

Joint trend: 355 vertical
330 vertical

2 4 0257

Subject 903-6319 Date 11/6/90 By R. Koth / R. Venkatakrishnan

Map Sta 4 cont

massive cocina bed with more thinly bedded, red, silceous parting below

— massive (~10')

— red parting (~3 to 1/4") to red laminations (weathered phosphate)

5 average trend of outcrop 350

From	to	Joint	Descript
0	0	270 ver	6" spacing
0	2	36 85S	10" spacing
2	4	278 72N	n.d.
		48 56E	weakly penetrative
4	5	312 ver	bedding plane seep (dry)
5	8	225 ver	A-type (anastomosing)
8	9	205	
9	23	288	open, planar, ..., solutioning, calcite coated
23	27	272	planar, calcite coated
27	28	132	
28	49		outcrop w/ minor joints
49	75		no outcrop (covered)
75	85	289	planar, penetrative
85	86	180	planar, tight
86	93	130	thinspaced, ~6", A-type
93	98	276	irregular to planar, A-type
98	106	268	irregular to planar
106	111	275 47N	- calcite coating, penetrative planar
111	119	286	- highly solutioned, irregular

Subject 903-6319 Date 11/6/90 By R. Koth / R. Venkatakrishnan

Map Sta. 3 cont

Minor seeps along calcareous shale partings, @ corner of building good for sampling

Secondary solution enlargement along same bed as seep behind building (between RR and rear of building)

Major seep between incinerator and corner of building, same bedding plane (~1 to 2 gal/min

N330 72W penetrative throughout outcrop

4 Same as 2 except larger shell fragment, which are pref. weathered to form solution pits, little coarser grained than #2

Cross stratification, gentle NW dip, current bedded

Joints

128

122 85NE

joint surfaces are wavey due to cross stratification & current beds

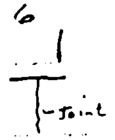
2 4 0203

Subject 903-6319 Date 11/6/90 By R. Kath / R. Venkatakrishnan

Map Sta	
6	med to coarse grd, highly cross stratified, red laminated, bio clastic limestone, light gray to gray
7	Below hump tower Outcrop N10

Joints 132 ver slightly stained, open
30 ver irregular, penetrative
109 steeps irregular, closed
106 ver

some joints are distracted in red argillaceous layers, Rock type same as 6


T-joint

argill
massive bioclastic lst

62 ver irregular, semi-planar, pene.

Outcrop continues from hump house to control tower

8 From To Joint Desc.
0 290 major penetrative, smooth, forms cliff wall, 36 to 40' sp. @ tri point (toward bridge) collapsed sol features, sec. enlargment of Joints & x-stratif. in bio clastic lst

Subject 903-6319 Date 11/6/90 By R. Kath / R. Venkatakrishnan

Map Sta

5

From	To	Joint	Desc
119	125	15 ver	coarse grd bioclastic - old sink hole in this interval, penetrative, somewhat irregular, open old sink hole
(picture #1)			
131	140	274	
@ 140			end of outcrop

6 directly east of hump house tower Bigby-Canon Formation Same as 2 strike of outcrop N18°

Joints:
338 ver
341 ver
245 irregular
270 tight
282
18 steeply to west
150 ver
142 steeply to South
132 83N irregular, tight
100 72N
94 ver tight, planar
138 ver high penetrative
48
102 78N

2 4 0239

Subject 903-6319 Date 11/6/90 By R. Kath / R. Venkatakrishnan

Map Sta 8 cont

Int	Joint	Desc
21	300	- 1m spacing, penetrative
32	140	- penetrative, semi-smooth soil filled in one section
35	105	- 18" spacing
36	121	- penetrative, semi-planar
40	126	- planar, semi-penetrative
43	128	- ~1ft spacing (same as 40)
48	282	- open ~ ½ to 1", penetrative, planar
	218	- non-penetrative, weak
53	192	- penetrative, semi-planar
67	129	- seep on west facing wall
77		- seeps on both walls, red partings @ top of west facing wall
87	309	- wet, seeps, penetrative planar.
100	165	- planar, penetrative
108	112	- dry seep w/moss, 6" spac fissure type
109	270	- 6" to 8" spacing, semi-planar
	169	- penetrative, planar
126	300	- old seep along joint, penetrative, lichen on all faces and dry moss. Seep coming out of shale partings.
	195	- semi-penetrative.
142	355	- seeps on shaly partings, planar, semi-penetrative
	190	- semi-penetrative, smooth
155	307	- semi-planar to planar?
	306	- penetrative 30" spacing

Subject 903-6319 Date 11/6/90 By R. Kath / R. Venkatakrishnan

Map Sta 8 cont

From	To	Joint	Desc
0	16	265	extensive seep flowing down wall, minor oil, wet
16	23	305	gray, x-strat, bioclastic lst
23	42	200	closely spaced, fissures
		180	semi-planar, reddish partings bioclastic lst.
	59		intersection of track
	64	105	- 1m spacing, penetrative
	68	111	- 30" spacing, penetrative same Rx @ 6+5
90 - 99			Tunnel entrance - very massive (~4.5-5.0') thick bed at top before tunnel

from east side of tunnel, going uphill toward round house

Int	Joint	Desc
0	168	- planar, penetrative
6	270	- bedding plane seep
	278	- penetrative, semi-planar Picture #2
12	300	- penetrative, 12 to 14" spacing smooth, planar
15	175	- semi-planar, weakly penetrat.
18	305	- 1m spacing
23	175	- steep easterly dip
12-30		seeps ~ 5' above bed of RR track (5' to 14" interval wet w/ moss)
21	190	- 1m spacing

2 4 0240

Subject 903-6319 Date 11/6/90 By R. Koth / R. Venkatakrishnan

Map Sta 8cont	Int	Joint	Description
	298	131	- penetrative, planar

9 Carters limestone, West side of Nville Pike north of Elysian Field Rd, @ ~ Rd level light gray to med gray, massive bedded, solutioned, fossiliferous limestone

Fossils include: silicified crynoid stems, brachs?, ~~pelo~~ and colonial corals

Minor bioturbated and fossil lag or hash type beds

Karst features include: solution enlarged joints, pockets, scalloping, cavities, stylolitic bedding surfaces, clay infilling in solution channels

Outcrop face dir: 140

Joints: 255 tight, planar,
252 34" spacing
255 tight, penetrative

Nville = Nolsenville

Subject 903-6319 Date 11/6/90 By R. Koth / R. Venkatakrishnan

Map Sta 8cont	Int	Joint	Desc.
	166	210	- penetrative, semi-planar
	175	302	- minor seeps along shale partings, E & N walls
east wall	185	122	- penetrative, smooth
	190	118	- semi-penetrative
		114	- penetrative, planar, minor seep
	192	138	- good seep, penetrative
	196	132	- good seep, semi-penetrative
		129	- penetrative, irregular fissure type, closed
west wall	208	220	- dissolut in argillaceous bed, semi-penetrative, semi-planar to fissure
Straight sec of track		210	- " " ~38" spacing
	213	228	- penetrative to semi-pene. dissolut toward top, semi-planar, smooth
			- top bed has stratomile man[illegible] ~1'. soil thickness
2A3	230	130	- 1 to 1.5 m spacing along 30' section along top of outcrop.
	262	130	- space ~ 6" on a couple then until next one none are seen // 9 // ↑ // ~ 6" 17 to 20' 17 to 20'
	277	310	- massive bed described @ 90-99 interval ~ 4.5 to 5.0 ft
		192	- orthogonal set?
	297	128	- semi-penetrative, 4 within 15"

Subject 903-6319 Date 11/6/90 By R. Koth / R. Venkatakrishnan

Map Sta.			
11	Ry: same as 10		
NE	Joints:		
	0	270	· Open to filled, ~½", semi planar
		N-S	penetrative
	6	283	· planar, penetrated, closed
		269	- semi · penetrative
	59	–	0-59 covered, @ 59 jointed although rotated blks.
	80	–	59-80 covered, 80 same as 59
	100	–	- med to nodular bedded channel gravels composed of shell debris. Near NE End of island.
	from pt to SW end of island		
	0	262	- semi · planar, penetrative
	6	245	- planar, penetrative
	9	235	- Irregular, semi penetrat.
	33	87	- SW end of island, toward hump tower planar, penetrative, tight
	11/7/90		
12	South Side of Bridge looking north		
	Int	Joint	
	0	243	- bedding plane scour
	9		Bridge (S-side) -possible sinkhole under bridge

Subject 903-6319 Date 11/6/90 By R. Koth / R. Venkatakrishnan

Map Sta.

10

Joints

50 ver — penetrative, smooth/planar
55 ver — 12" spacing
52

Bighy-Canon:
Fine to med, dove gray bioclastic limestone w/ micrite intraclasts and minor nodular chert, minor calcite (dogtooth) filled vugs, irregular bedding planes

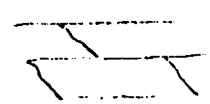
-between Map Sta and end of bld minor sink hole filled w/ trash, joints near sink trend:
105 — minor solution activity along bedding planes and joint faces
98 - planar

-between tracks @ end of bld. (two nearest bld)
355 penetrative, semi-planar
-across from sinkhole, between tracks
258 semi-planar, penetrative
252 curvilinear, smooth

2 4 0242

Subject 903-6319 Date 11/7/90 By R. Kath / R. Venkatakrishnan

Map Sta. 12int	Int	Joint	Desc.
		242	- semi-planar, semi-penetrative
	226	248	- semi-penetrative
	240		- Best outcrop along traverse next to poles
		180	- open, vertical, no fill
		78	- penetrative, semi-planar
	245	145	
	252	100	- penetrative, smooth
		56	- semi-penetrative, irregular
		140 dip (30°)	- gently sloping, fracture, rhomb fracturing, smooth
		(Picture)	pervasive fabric, semi-penetrative. jogs between beds



13 along I-65 Northbound lane
Hermitage Fm (outcrop trends 175)
working from south toward north
(probably upper Hermitage)

Int	Joint	Desc
	35	- solution opened, sol. etching
	40	- penetrative
	29	- sol. etched, penetrative, pene
	70	- penetrative, irregular
	55	- open 3/4", penetrative, planar
	135	- open 3-4", sol enlarged, planar
	80	- misplaced bore hole ~ 1" movement horizontally no vert. disp.
		- some bedding plane ll dissol

Subject 903-6319 Date 11/7/90 By R. Kath / R. Venkatakrishnan

Map Sta. 12cmt	Int	Joint	Desc
	North side of	Bridge	working toward north
	62	N-S	- penetrative, semi-planar
		82	- semi-penetrative, smooth to fissure
		136	moss on rx suggesting possible old seep area
	98	235	- face forming, penetrative, planar
		92	- penetrative, semi-planar
		218	- semi-penetrative, irregular
	129	170	- penetrative, planar
		65	- semi planar
		173	- penetrative,
		118	- semi planar, semi-penetrative
		230	- all in bed ll sol, in fossil lst w/ x-strat.
	150	235	- face forming joint, penetrative extensive bedding ll solution bioturbated, fossiliferous gray lst
		90	- penetrative, semi-planar
	180	270	- planar, penetrative
		92	- semi-penetrative
		90	" " , semi-planar
	193	220	- penetrative, irregular / semi-planar
		100	- 6" spacing, penetrative
		60	- 8" spacing, penetrative
	202	242	- penetrative, face former
	214	135	- curvilinear into bedding plane

Subject 903-6319 Date 11/7/90 By R. Venkatakrishnan / R. Kath

Map Sta.		
13	Joint	
	130	-planar, ~~irr~~ irregular, penetrative minor secondary enlargement
	60	-sol enlarged, etched, open
	80	-semi-penetrative, irregular
	40	-etched, semi-planar, semi-pen.
	130	-etched, semi-planar, penetrative
	136	-sol enlarged, semi-penetrative semi-planar
	75	-open, sol. enlarged, semi-planar to fissure
	→	top 10 to 15' of outcrop is epi-karstic
	minor seeps south of major overpass interchange, bedding parallel	
14	Upper Hermitage Fm	
	Outcrop trends along railroad N35	
	Start at N end of long building	
	0 190	-penetrative, planar
	285	-semi-penetrative, bedding parallel collapses
	13 195	
	17 230	semi-pen., planar, tight
	46 235	-bedding parallel solution, semi-pen, planar
	63 300	bedding ‖ scallops
	205	- semi-penetrative [illegible]
	73	-gentle dip to N-NW

0244 24

GEOLOGIC MAPPING DETAILS

Based on the results of the geologic mapping and soil boring programs, the Radnor Yard is underlain by fill materials overlying a mantle of clayey silt, and the underlying Ordovician Bigby-Cannon Formation. All bedrock outcrops on site contained lithologies characteristic of the Bigby-Cannon Formation whereas other outcrops in the immediate site vicinity are within the Carters Formation (east-northeast of the site), the Hermitage Formation (north of the site) and Leipers-Catheys Formation (west of the site).

Previous investigations by Wilson (1949) and Allen (1937) have shown the upper tributaries of the east fork of Browns Creek, directly beneath the northern classification yard, have eroded into the Hermitage Formation. This area is now inaccessible due to the filling of these valleys in the 1950's. Although the Hermitage Formation may have been exposed beneath the northern part of the classification yards, the only exposure of the Hermitage Formation near the site is located behind an abandoned factory along the western side of the Seaboard Railroad Track northwest of the Radnor Yard. The elevation of this outcrop, taken from 5-foot contour maps (1984), is about 540 feet MSL; dip direction is generally to the south. The southerly dip is consistent with the occurrence of Bigby-Cannon Formation exposed behind the LP gas plant approximately 2000 feet south-southeast of the exposed Hermitage Formation.

Further evidence which suggest the general absence of exposed Hermitage Formation beneath the site is a small outcrop immediately down stream of the oil booms on Browns Creek. This outcrop is topographically the lowest area immediately adjacent to the Radnor Yard (approximately 550 ft-MSL). Using the published geologic map, this area should be within the Hermitage Formation. The rocks exposed in the creek, however, are more characteristic of the Dove-colored facies of the Bigby-Cannon Formation (see Wilson, 1949).

As previously mentioned, the only exposed litho-stratigraphic formation at the Radnor Yard is the Bigby-Cannon Formation. In order to understand any lithologic or structural discontinuities, other formations which are exposed adjacent to and around the site were examined. Features such as karst geomorphology, structures, lithologies, and jointing and bedding orientations were noted. Using the regional stratigraphic column, the general sequence is (from oldest to youngest) 1) Carters, 2) Hermitage, 3) Bigby-Cannon, and 4) Leipers-Catheys Formations.

The massive Carters Formation is the oldest formation exposed in the Browns Creek area. This formation was observed in two outcrops along the west side of Noseville Pike, just north of the intersection of Elysian Fields Road and Noseville Pike and behind a shopping mall southwest of the Elysian Field/Noseville Pike intersection. At these locations, the Carters Formation is composed of a dense, massively-bedded, gray crystalline limestone. Individual beds range from one to four feet in thickness. Chert occurs both as long lens-like beds and as "flatland" nodules. Bedding planes are generally stylolitic and show minor secondary solution enlargements. Silicified colonial corals are abundant and are characteristic of this formation.

Joints were observed at these outcrops, although measurements were difficult due to secondary solution enlargement causing irregular surfaces. Some of the joints exhibit only minor solutioning; therefore, these were measured. The trends of these measurements are illustrated on a rose diagram for map stations 13 and 14.

The Hermitage Formation was observed in two places: along I-65 south of the interchange with I-440 in a deep road cut, and behind an abandoned factory northwest of the oil boom in Browns Creek. The Hermitage Formation is characteristically a thinly bedded, fossiliferous, argillaceous limestone. Locally brown to black phosphate grains were observed. The Hermitage Formation is usually described as "ribbon rock" due to the alternating coquina and argillaceous beds. The argillaceous zones are generally fine to medium-grained, gray to buff gray, thinly bedded to laminated, calcareous siltstone/argillite.

As previously noted, all of the outcrops within the Radnor Yard boundary are composed of various facies of the Bigby-Cannon Formation. The best exposures are located along the east side of the large knob in the southwestern corner of the yard, behind the large building south of the oil booms in Browns Creek, and in a deep railroad cut located along the northern side of the site.

The Bigby-Cannon Formation comprises three distinct and mappable facies: 1) Bigby facies, 2) Dove-Colored facies, and 3) Cannon facies. Furthermore, the Bigby facies can be sub-divided into an upper, middle and lower facies. Based on Golder's Associates geologic field investigation, only the Bigby and Dove-Colored facies were encountered. This is consistent with the interpreted facies relations described by Wilson (1949). Wilson suggests that the Cannon facies would lie further to the east of the site.

The Bigby facies consists of a blue-gray (when fresh), bioclastic limestone which contains both phosphatic specks and laminae. The laminar phosphates generally weather to a characteristic reddish-brown color. These laminations are characteristic of many of the outcrops observed within the Radnor Yard area.

The Bigby facies generally rests upon the coquina member of the underlying Hermitage Formation. Although the contact was not directly observed in the field, it is inferred to occur between the 540 and 550 ft-MSL contour lines northwest of the site. These elevations are based on the exposed Bigby-Cannon and Hermitage Formation outcrops.

Although it is often difficult to identify the Bigby facies on the basis of lithology, several factors are characteristic of the lower Bigby facies. For example, the lower Bigby facies is generally a medium to coarse-grained, bluish-gray to brown, bioclastic limestone which contains phosphatic laminae, cross stratification, and silicified-broken fossils. All outcrops within and around the Radnor Yard contain these characteristics except the deep cuts southwest of the oil boom and the deep railroad cut along the northern edge of the site. Therefore, the central and southern outcrops within the Radnor Yard have been assigned to the lower Bigby facies of the Bigby-Cannon Formation.

In the Nashville area, the Dove-Colored facies of the Bigby-Cannon Formation is named from the dove-color of the limestone, when relatively unweathered. The Dove-Colored facies consists of light-gray or dove-colored, very pure limestone interbedded with thin silt and clay partings. Bedding is generally thick to massive, but varies from an inch to several feet, and averages about one foot. Due to its fine-grained, dense and brittle nature, the limestone has a characteristic conchoidal fracture. A common feature is the occurrence of specks and vertical stringers of clear calcite, resembling the "birdseye" limestones described in New York.

Based on the isopach maps of the Dove-Colored facies (Wilson, 1949), the Dove-Colored facies at the Radnor Yard is about 12 to 15 feet thick, whereas the Bigby facies is up to 70 feet thick. However, because the Dove-Colored facies occurs as lenses interbedded with the Bigby facies, the thickness may vary from virtually absent to 15 feet at the Radnor Yard.

As previously mentioned, all of the Bigby-Cannon outcrops have characteristics of the Bigby facies except for the northernmost outcrops (i.e. north of the Round House). These outcrops contain intermixed rocks characteristic of the Bigby facies and rocks characteristic of the Dove-Colored facies. The Dove-Colored facies at these locations includes medium-bedded, fine-grained, conchoidal fractured, gray to light-gray limestone interbedded with thinly-bedded (<1 inch), tan, silty calcareous, fine-grained sandstone. These characteristic Dove-Colored facies lithologies are interbedded with cross-stratified, bioclastic limestone (lower Bigby facies).

Detailed geologic investigations by Allen (1937) and Golder Associates in the Browns Creek area reveal gently dipping strata toward the east, west, northeast and northwest. Dip values range from nearly flat to a maximum of 8 degrees. The variations in strike and dip direction are consistent with the small scale structures illustrated on the regional structure contour maps. These small scale folds appear to be superimposed upon the broad gently dipping limbs and crest of the Nashville dome. These irregular small-scale structures account for the considerable variations measured in strike and dip direction at the Radnor Yard.

During the geologic field investigation, Golder Associates did not observe the Hermitage/Bigby-Cannon contact at the Radnor Yard due to the relatively small area at the site and the presence of the filled valleys. However, Allen (1937) describes the structure of the Browns Creek area as a series of very irregularly shaped anticlines and synclines, suggestive of no pattern in the orientation of their axis.

Allen (1937) made note of small scale minor faults with little displacement and of joints. During this detailed geologic investigation, Golder Associates did not see any faults at the Radnor Yard, although bedding and joint sets were prevalent.

Bedding was strongly developed at each outcrop at the Radnor Yard. Bedding ranged from massive to thinly bedded and planar to irregular to current modified. Throughout the site, bedding was gently dipping with no consistent dip direction. The apparent randomness in bedding dip direction illustrates the presence of small scale, irregular structures which are superimposed on the larger scale Nashville dome. These small-scale flexures can be envisioned as representing an undulating surface with an overall gentle dip to the south and southeast.

All outcrops within and around the Radnor Yard contain pervasive joint sets. Two prominent sets were measured throughout the area, N130° and N270°. These orientations were penetrative on the outcrop scale and throughout all outcrops, thus penetrative on a regional scale. Other joint sets were observed but did not daylight in all outcrops due to the outcrop orientation.

Joint sets were classified using the following terms: penetrative or semi-penetrative; planar, semi-planar, or fissure; open or closed; calcite-coated or barren; and solutioned or non-solutioned. The outcrop orientation was recorded as well as joint set orientation and characteristics. Based on the cumulative rose diagrams, two major penetrative joint orientations are noted, N306°-314° and N285°. The orientation of these joints is consistent with joints measured throughout the Nashville dome.

Because bedrock outcrop extent within the Radnor Yard is limited, vertical karst development is not readily observable. Therefore, a search for karst landforms was conducted in the surrounding area. The reason for this search was to document the types and morphologies of karst landforms and other solution features that have developed in the bedrock. Because the bedrock beneath the Radnor Yard is the same as those in the surrounding areas, it is possible that the karst morphology at the site would be the same as that present in nearby areas.

The beltway I-440 around the city of Nashville provided some of the best exposures along engineered road cuts. The outcropping formations along the interstate were the Leipers, Catheys, Bigby-Cannon, and Hermitage Formations. Large scale karst landforms, mostly collapse and solution sinkholes, are readily observed along I-440. Nolesville Pike to the east of the site, along Sevenmile Creek, also provided excellent examples of solution and collapse karst features developed in the Carters Limestone. Road cuts along I-65, just north of the site, provided at least 25 feet of vertical exposure through the Hermitage Formation.

Sinkholes are clearly expressed in the Bigby-Cannon Limestones exposed along the I-440 road cut south of Nashville, and just west of the I-65 interchange. The development of epikarst (zone of highly corroded bedrock) is pronounced, and because the bedrock dips at very gentle angles, the level of epikarst develoment is also more or less planar and occurs upto a depth of about 20 feet beneath the ground surface. Bedding planes are solutionally enlarged, and joint faces are scalloped and stained by dissolution of bedrock. The karst is of the sub-soil variety. Soil is well developed on the upper slope of the cut and infills the sinkholes. The largest sinkholes appear to have captured or arrested further development of the other, smaller sinkholes and their necks appear to have penetrated depths beyond the epikarst zone. As the sinkholes enlarged, bedrock ledges collapsed into the enlarging soltion cavity thus displaying both solutional and collapse features of sinkhole development. It may be speculated that the intensity, close proximity, and scattered occurrence of these sinkholes has resulted in dentritic network cave passages in the area. Such cave passages and subsurface conduits are most probably along bedding planes with local structural control by joint planes where vertical hydraulic gradients may be steep. A similar scenario may exist beneath the Radnor Yard. Bedding control on solution features was clearly evident in the outcrops throughout the site. The Hermitage Formation is not exposed near the site, but the solution features observed along I-65 due north of the site suggest that karst development in this formation will be similar to those in the Bigby-Cannon, bedding controlled conduit systems with local effects by joint systems.

APPENDIX B

BOREHOLE LOGS

RESOURCE
CONSULTANTS

2 4 0255

Boring Log

JOB NO. 903-3174 GA. INSP. JMF PROJECT RDI/CSX/TN BORING NO. BH-1
DEPTH HOLE 23.5 DEPTH WL 7.9 DRILLING METHOD AUGER / AIR ROTARY SHEET 1 OF 1
TEMP 60° TIME WL 7:20 11/28/90 DRILLING COMPANY LAYNE ENVIRONMENTAL SURFACE ELEV. 592.0
WEATHER CLOUDY DRILL RIG GUS PECH 1000R DRILLER T. O'BRIANT DATUM MSL
COORDINATES N 640465.5047 E 1746249.3929 WT. SAMPLER HAMMER 140 DROP 30" STARTED 3:40 11/26/90
LOCATION CSX RADNOR RAILYARD WT. CASING HAMMER ___ DROP ___ COMPLETED 8:40 11/27/90

ELEV. DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
2.5	3.0	FIRM BROWN SILT, LITTLE CLAY, LITTLE LS GRAVEL FILL MATERIAL	N/A	11	SA-1	DO	2-3-8-6	5/24	
5.0		SOFT DARK BROWN SILT, TRACE TO SOME CLAY, TRACE TO LITTLE F. SAND							NOTE: SAMPLES SA-1 THROUGH SA-4 HAVE DIESEL AND OIL CONTAMINATION
7.5			ML	7	SA-2	DO	2-3-4-5	24/24	W.L
10.0									
12.5			ML	10	SA-3	DO	3-6-4-7	4/24	
15.0	15.9		ML	8	SA-4	DO	5-4-4-5	24/24	
	16.5	HARD GRAY BIGBY CANNON LIMESTONE							
17.5	19.0	VOID							
20.0		HARD GRAY, FINE GRAINED BIGBY CANNON LIMESTONE					RQD 62 %		
22.5	23.5		N/A	N/A	RC-1	ROCK CORE		4.5/5.0	
25.0		END OF BORING @ 23.5' BGS							
27.5									
30.0									

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2/4/91

Boring Log

JOB NO. 903 3174	GA. INSP. JMF	PROJECT RCI / CSX INV / TN		BORING NO. BH-2	
DEPTH HOLE 34.0	DEPTH WL. 24.1	DRILLING METHOD AUGER AIR ROTARY		SHEET 1 OF 1	
TEMP 45°	TIME WL. 9:30 11/29/90	DRILLING COMPANY LAYNE ENVIRONMENTAL		SURFACE ELEV. 601.0	
WEATHER OVERCAST		DRILL RIG GUS PECH 1000R	DRILLER T. O'BRIAN	DATUM MSL	
COORDINATES N641243.4820 E 1746352.8094		WT. SAMPLER HAMMER 140	DROP 30"	STARTED 8:25 11/28/90	
LOCATION CSX RADNOR RAILYARD		WT. CASING HAMMER	DROP	COMPLETED 10:30 11/23/90	

ELEV. DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
2.5		'FILL MATERIAL' VERY DENSE GRAY LIMESTONE BOULDERS, ROCK FRAGMENTS AND GRAVEL, SOME SOFT BROWN SILT, LITTLE CLAY, TRACE WOOD FRAGMENTS AND BLACK CINDER.	N/A	15	SA-1	DO	15-10-5	14/18	
5.0									
7.5			N/A	50+	SA-2	DO	47-50 FOR 3 IN.	6/9	
10.0									
12.5									NOTE: SAMPLES SA-1 AND SA-5, HAVE DIESEL AND OIL CONTAMINATION
15.0			N/A	55	SA-3	DO	5-5-50 for 4"	2/16	
17.5			N/A	7	SA-4	DO	3-3-4	18/18	
20.0									
22.5	22.0	FIRM, BROWN SILT TRACE TO LITTLE CLAY, TRACE F. SAND, TRACE GRAVEL	ML	23	SA-5	DO	8-9-14	18/18	
25.0	25.5								W.L.
27.5		HARD GRAY FINE GRAINED 'BIGBY CANNON LIMESTONE							
30.0									
32.5									
35.0	34.0	END OF BORING AT 34.0' BGS.							

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2-4-91

Boring Log 2 4 0255

JOB NO. 903-3174 GA. INSP. JMF PROJECT RCI / CSX INV / TN BORING NO. BH-3
DEPTH HOLE 39.75' DEPTH WL 22.9 DRILLING METHOD AIR HAMMER / AIR ROTARY SHEET 1 OF 1
TEMP 55° TIME WL 7:00 11/16/90 DRILLING COMPANY LAYNE ENVIRONMENTAL SURFACE ELEV. 604.0
WEATHER CLEAR DRILL RIG GUS PECH 1000R DRILLER T. O'BRIANT DATUM MSL
COORDINATES N 640845.8738 E 1746689.4515 WT. SAMPLER HAMMER 140 LB DROP 30 INCHES STARTED 2:00 11-15-90
LOCATION CSX RADNOR RAIL YARD WT. CASING HAMMER DROP COMPLETED 10:00 11-16-90

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
2.5			N/A	15	SA-1	DO	3-6-9-4	21/24	
5.0		"FILL MATERIAL" HARD GRAY LIMESTONE BOULDERS, ROCK FRAGMENTS AND GRAVEL, AND DK. BROWN SILT, LITTLE TO SOME CLAY.							NOTE: NO SAMPLES TAKEN FROM 3.0 to 24.0 FT. BGS. BECAUSE OF LARGE BOULDERS AND ROCK FRAGMENTS
7.5									
10.0									SAMPLES SA-1 AND SA-2 HAVE DIESEL AND OIL CONTAMINATION
12.5									
15.0									
17.5									
20.0									
22.5									W.L. ?
	24.0								
25.0		Firm DARK BROWN SILT, TRACE CLAY.	ML	28	SA-2	DO	6-16-12-12	18/24	
27.5									
30.0					RC-1	RC	ROCK CORE		
32.5				N/A	SA-3	DO	N/A	N/A	
					RC-1	RC	ROCK CORE	18/60	
35.0	35.0								
37.5		HARD, GRAY FINE GRAINED BIGBY CANNON LIMESTONE			RC-2	RC	ROCK CORE	58/60	
40.0		END OF BORING AT 39.75' BGS.							
42.5									
45.0									
47.5									

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2-4-91

Boring Log

JOB NO. 903-3174	GA. INSP. JMF	PROJECT RCI / CSX INV/TN		BORING NO. BH-3A	
DEPTH HOLE 30.0	DEPTH WL. 20.2	DRILLING METHOD AIR HAMMER		SHEET 1 OF 1	
TEMP 45°	TIME WL. 7:10 1/16/91	DRILLING COMPANY MILLER DRILLING		SURFACE ELEV. 600.0	
WEATHER RAIN		DRILL RIG SCHRAM T-450	DRILLER S. PRINCE	DATUM MSL	
COORDINATES N640827.0347 E 1741646.0576		WT. SAMPLER HAMMER 140	DROP 30 INCHES	STARTED 4:45 1-10-91	
LOCATION CSX RADNOR RAIL YARD		WT. CASING HAMMER	DROP	COMPLETED 4:00 1-15-91	

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES HAMMER BLOWS PER 6 IN.	SAMPLES REC./ATT	REMARKS
0 / 2.5 / 5.0 / 7.5		"FILL MATERIAL" HARD GRAY LIMESTONE BOULDERS, ROCK FRAGMENTS AND GRAVEL, AND DK. BROWN SILT, LITTLE TO SOME CLAY.							NOTE: SAMPLES SA-1 THROUGH SA-4 HAS DIESEL AND OIL CONTAMINATION
10.0			N/A	10	SA-1	DO	56-6-4-4	6/24	
12.5			N/A	3	SA-2	DO	4-1-2-3	16/24	
15.0									
17.5			N/A	53	SA-3	DO	10-30-23-30	12/24	
20.0	21.0								W.L.
22.5		FIRM TO STIFF, TAN TO ORANGE BROWN SILT, TRACE TO LITTLE CLAY, LITTLE F. SAND.	ML	29	SA-4	DO	10-13-16-11	24/24	
25.0		CEMENTED STRINGERS OF F. SAND (27.5 - 30.0)							
27.5			ML	36	SA-5	DO	16/18/18/20	20/24	
30.0	30.0	HARD GRAY BIGBY CANNON LIMESTONE END OF BORING AT 30.0' BGS.							
32.5 / 35.0									

2 4 0237

Boring Log

JOB NO. 9033174 QA. INSP. JME PROJECT RCI/CSX INV/TN BORING NO. BH-4
DEPTH HOLE 39.6 DEPTH WL 21.3 DRILLING METHOD AIR ROTARY / AUGER SHEET 1 OF 1
TEMP 65 TIME WL 7:00 11/26/90 DRILLING COMPANY LAYNE ENVIRONMENTAL SERV SURFACE ELEV. 535.0
WEATHER CLEAR DRILL RIG GUS PECH 1000R DRILLER J. OBRIANT DATUM MSL
COORDINATES N 640273.2484 E 1746292.7303 WT. SAMPLER HAMMER 140 DROP 30 INCHES STARTED 8:30 11/21/90
LOCATION CSX RADNOR RAILYARD WT. CASING HAMMER DROP COMPLETED 12:30 11/21/90

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: HAMMER BLOWS PER 6 IN.	SAMPLES: REC./ATT	REMARKS
0.0	1.0	ASPHALT AND GRAVEL							
2.5		SOFT, BROWN CLAY SOME TO AND SILT	N/A	17	SA-1	DD	9-9-8-9	18/24	
5.0		"FILL MATERIAL"							NOTE: SAMPLE SA-1-SA-2 HAVE DIESEL AND OIL CONTAMINATION
7.5			N/A	6	SA-2	DD	1-3-3-4	12/24	
10.0									
12.5	11.5	SOFT BROWN SILT TRACE TO LITTLE CLAY	ML	6	SA-3	DD	2-3-3-3	22/24	
15.0									
17.5			ML	11	SA-4	DD	2-6-5-5	22/24	
20.0									W.L.
22.5			ML	46	SA-5	DD	11-21-25-33	24/24	
25.0									
27.5			ML	NA	RC-1 SA-6	RC	CORED	18/60	
30.0	29.6	FIRM GRAY SILT AND FINE SAND, LITTLE CLAY. SAND LENS (F-M) FROM 31.2-31.5	ML	20	SA-7	DD	3-5-20-23	20/24	
32.5									
35.0									
	36.6	HARD GRAY TO WHITE WEATHERED AND FRACTURED BIGBY CANNON LIMESTONE		NA	RC-2	RC	CORED	36/36	
40.0	39.6	END OF BORING AT 39.6' BGS							

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2-4-91

Boring Log

JOB NO. 903 3174 GA. INSP. JMF PROJECT RCI /CSX INV / TN BORING NO. RH-5
DEPTH HOLE 37.0 DEPTH WL. 19.3 DRILLING METHOD AIR ROTARY SHEET 1 OF 1
TEMP 45° TIME WL. 3:00 11/18/90 DRILLING COMPANY LAYNE ENVIRONMENTAL SURFACE ELEV. 600.7
WEATHER CLEAR DRILL RIG GUS PECH 1000R DRILLER T. O'BRIANT DATUM MSL
COORDINATES N 641069.3555 E 1746395.2489 WT. SAMPLER HAMMER 140 DROP 30-INCHES STARTED 9:00 11/18/90
LOCATION CSX RADNOR RAILYARD WT. CASING HAMMER DROP COMPLETED 4:30 11/18/90

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES: NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
2.5		FILL MATERIAL' SOFT TO FIRM, BROWN CLAY, SOME TO AND SILT, AND HARD GRAY BOULDERS, ROCK FRAGMENTS AND GRAVEL	N/A	30	SA-1	DO	5-5-21-5	6/24	NOTE: SAMPLES SA-1 THROUGH SA-4 HAVE DIESEL AND OIL CONTAMINATION
5.0									
7.5			N/A	31	SA-2	DO	5-5-26-28	6/24	
10.0									
12.5			N/A	30	SA-3	DO	8/22 FOR 12"	3/24	
15.0									
17.5			N/A	9	SA-4	DO	3/6 FOR 12"	3/24	
20.0	19.2	SOFT DARK BROWN SILT, LITTLE CLAY	N/A	NA	RC-1	ROCK CORE	RQD 0%	0/60	W.L
22.5									
25.0									
27.5			ML	12	SA-6	DO	3-5-35	0/24	
30.0									
32.5	31.5	HARD GRAY FINE GRAINED 'BIGBY CANNON LIMESTONE'							
35.0				NA	RC-2	ROCK CORE	RQD 70%	60/60	
37.5	37.0	END OF BORING AT 37.0' BGS							
40.									
42.5									

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 7-4-91

Boring Log

JOB NO. 903 3174 GA. INSP. JMF PROJECT RCI / CSX INV / TN BORING NO. BH-5A
DEPTH HOLE 55.0' DEPTH WL. 25.2 DRILLING METHOD AIR ROTARY / AIR HAMMER SHEET 1 OF 1
TEMP 45° TIME WL. 7:20 1/17/91 DRILLING COMPANY MILLER DRILLING SURFACE ELEV. 600.7
WEATHER CLOUDY DRILL RIG SCHRAM T-450 DRILLER S PRINCE DATUM MSL
COORDINATES N641073.7387 E1746394.2717 WT. SAMPLER HAMMER 140 DROP 20 - INCH STARTED 8:00 1/16/91
LOCATION CSX RADNOR RAILYARD WT. CASING HAMMER DROP COMPLETED 11:05 1/16/91

ELEV. DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
2.5 – 20.0		'FILL MATERIAL' (SEE BH-5 LOG)							NOTE: NO SOIL SAMPLES TAKEN SEE LOG FOR BH-5
21.0 – 30.7	21.0	SILT ZONE W/O ROCK FRAGMENTS	ML						W.L (25.0)
30.7 – 48.0	30.7	'HARD GRAY, FINE GRAINED' BIGBY CANNON LIMESTONE.							
48.0 – 55.0	48.0	HERMITAGE LIMESTONE HARD DK. GREEN TO DK. BROWN FOSSILIFEROUS LIMESTONE							CHANGE IN COLOR OF CUTTINGS FROM LIGHT GRAY TO DARK BROWN AT 48.0 FT BGS.
55.0	55.0	END OF BORING AT 55.0' BGS							

Depth scale: 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0, 32.5, 35.0, 37.5, 40.0, 42.5, 45.0, 47.5, 50.0, 52.5, 55.0

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2-4-91

Boring Log

JOB NO. 903-3174 GA. INSP. JMF PROJECT RCI / CSX INV / TN BORING NO. RH-6
DEPTH HOLE 42.0 DEPTH WL 14.1 DRILLING METHOD AIR ROTARY SHEET 1 OF 1
TEMP 55° TIME WL 3:00 11/20/90 DRILLING COMPANY LAYNE ENVIRONMENTAL SURFACE ELEV. 586.2
WEATHER CLOUDY DRILL RIG GUS PECH 1000R DRILLER T. O'BRIANT DATUM MSL
COORDINATES N640167.8983 E1746289.9305 WT. SAMPLER HAMMER 140 DROP 30-INCHES STARTED 1:20 11/19/90
LOCATION CSX RADNOR RAILYARD WT. CASING HAMMER DROP COMPLETED 4:15 11/19/90

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES: NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
		LARGE RIP RAP HARD GRAY LIMESTONE BOULDERS, SOFT BROWN SILT AND CLAY							
2.5	4.0		N/A	12	SA-1	DO	4-6-8-3	0/24	NOTE: SAMPLES SA-2 THROUGH SA-6 HAVE DIESEL AND OIL CONTAMINATION.
5.0		FIRM BROWN AND BLACK SILT, SOME CLAY, TRACE GRAVEL	ML	15	SA-2	DO	5-7-8-10	15/24	
7.5									
10.0		NOTE: BLACK DISCOLORATION ON SAMPLES (2-7)	ML	10	SA-3	DO	4-4-6-9	0/24	
12.5									
15.0			ML	12	SA-4	DO	4-6-6-9	12/24	W.L.
17.5									
20.0			ML	11	SA-5	DO	1-4-7-4	23/24	
22.5									
25.0			ML	7	SA-6	DO	3-3-4-5	24/24	
27.5									
30.0			ML	5	SA-7	DO	3-2-3-4	24/24	
32.5									
35.0	37.2		ML	3	SA-8	DO	2/3 FOR 12"	0/24	
37.5		HARD GRAY FINE-GRAINED BIGBY CANNON LIMESTONE							
40.0	42.0			RQD 95%	RC-1	ROCK CORE	N/A	60/60	
42.5		END OF BORING AT 42.0' BGS.							
45.0									
47.5									
50.0									

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2-4-91

Boring Log

JOB NO. 903-3174	GA. INSP. JME	PROJECT RCI / CSX INV / TN		BORING NO. BH-7	
DEPTH HOLE 34.0	DEPTH WL 23.7	DRILLING METHOD AUGER / AIR ROTARY		SHEET 1 OF 1	
TEMP 45°	TIME WL 7:45 11/30/90	DRILLING COMPANY LAYNE ENVIRONMENTAL		SURFACE ELEV. 600.6	
WEATHER CLEAR		DRILL RIG GUS PECH 1000R	DRILLER T. O'BRIANT	DATUM MSL	
COORDINATES N640628.0421 E1746123.5812		WT. SAMPLER HAMMER 140	DROP 30-INCHES	STARTED 4:30 11/20/90	
LOCATION CSX RADNOR RAILYARD		WT. CASING HAMMER	DROP	COMPLETED 10:45 11/29/90	

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
0.0	1.0	ASPHALT AND LS GRAVEL							
2.5		'FILL MATERIAL'	N/A	22	SA-1	DO	12-13-91	16/18	
5.0		FIRM TO STIFF, BROWN SILT, LITTLE TO SOME CLAY AND GRAY LIMESTONE ROCK FRAGEMENTS AND GRAVEL AND BOULDERS							NOTE: SAMPLES SA-1 THROUGH SA-4 HAVE DIESEL AND OIL CONTAMINATION.
7.5									
10.0			N/A	50+	SA-2	DO	1/50 + FOR 12"	4/12	
12.5									
15.0			N/A	39	SA-3	DO	27-27-12	3/18	
17.5									
20.0									
22.5			N/A	32	SA-4	DO	12-12-20	4/18	W.L
25.0									
27.5	27.5		N/A	50+	SA-4	DO	6/50+ for 12"	6/18	
30.0		HARD GRAY, FINE GRAINED SLIGHTLY WEATHERED BIGBY CANNON LIMESTONE							
32.5	34.0		N/A	N/A	RC-1	ROCK CORE	RQD 36%	60/60	
35.0		END OF BORING AT 34.0' BGS.							

JOB NO. 903-3174	GA. INSP. JMF	PROJECT RCI / CSX INV / TN		BORING NO. BH-8	
DEPTH HOLE 43.0	DEPTH WL 25.2	DRILLING METHOD AIR HAMMER		SHEET 1 OF 1	
TEMP 45°	TIME WL 3:15 1/10/91	DRILLING COMPANY MILLER DRILLING		SURFACE ELEV. 598.2	
WEATHER PARTLY CLOUDY		DRILL RIG Schram T-450	DRILLER Steve Pearce	DATUM MSL	
COORDINATES N 640 949.9713 E 1746096.2643		WT. SAMPLER HAMMER 140	DROP 30-INCH	STARTED 3:15 1/7/91	
LOCATION CSX RADNOR RAILYARD		WT. CASING HAMMER	DROP	COMPLETED 7:00 1/14/91	

ELEV. DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
2.5		'FILL MATERIAL' FIRM BROWN TO DK. BROWN SILT, LITTLE CLAY, TRACE F. SAND, AND HARD GRAY LIMESTONE BOULDERS, ROCK FRAGMENTS AND GRAVEL.							NOTE: SAMPLE SA-4 HAS DIESEL AND OIL CONTAMINATION IN THIN SILT LAYER
5.0			N/A	13	SA-1	DO	10-6-7-10	4/24	
7.5									
10.0			N/A	15	SA-2	DO	4-6-9-9	14/24	
12.5									
15.0	15.0	'FILL MATERIAL' COMPACT BLACK MEDIUM SAND SIZED CINDER, SOME LARGE GRAY LIMESTONE BOULDERS	N/A	28	SA-3	DO	12-14-14-16	14/24	
17.5									
20.0			N/A	11	SA-4	DO	2-3-8-8	24/24	
22.5									
25.0									W.L
27.5									
30.0	31.0	FIRM DK. BROWN TO ORANGE BROWN SILT TRACE TO LITTLE CLAY, LITTLE F. TO MED. SAND FROM (36.8 TO 37.0)	ML	14	SA-5	DO	4-6-8-8	24/24	
32.5									
35.0									
37.5	37.0		ML	25	SA-6	D.O	12-13	12/12	
	38.0	HARD, GRAY BIGBY CANNON LIMESTONE							
40.0		VOID							
	41.5	HARD GRAY FINE GRAINED, BIGBY CANNON LIMESTONE							
42.5	43.0	END OF BORING AT 43.0 BGS.							
45.0									

JOB NO. 903-3174	Golder Associates	CHECKED JMF
SCALE AS SHOWN		DATE DRAWN 2-4-91

JOB NO. 903 3174 GA. INSP. ME PROJECT RCI / CSX INV / TN BORING NO. BH-9
DEPTH HOLE 37.0 DEPTH WL 22.0 DRILLING METHOD AUGER / AIR ROTARY SHEET 1 OF 1
TEMP 65° TIME WL 7:05 11/28/90 DRILLING COMPANY LAYNE ENVIRONMENTAL SURFACE ELEV. 600.7
WEATHER DRY CDY DRILL RIG GUS PECH 1000R DRILLER T. OBRIANT DATUM MSL
COORDINATES N641382.9685 E1746356.7324 WT. SAMPLER HAMMER 140 DROP 30-INCH STARTED 10:15 11/27/90
LOCATION CSX RADNOR RAILYARD WT. CASING HAMMER DROP COMPLETED 3:00 11/27/90

ELEV. DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
		LOOSE TO COMPACT BLACK CINDER AND COARSE GRAVEL (L.S.)							
2.5	3.0			11	SA-1	DO	5-6-54	6/24	
5.0		'FILL MATERIAL' FIRM BROWN CLAY, SOME TO AND SILT, SOME GRAY LIMESTONE BOULDERS, ROCK FRAGMENTS AND GRAVEL							NOTE: SAMPLES SA-1 AND SA-7 HAVE DIESEL AND OIL CONTAMINATION
7.5				12	SA-2	DO	5-6-6-9	5/24	
10.0									
12.5				50	SA-3	3" DO	10-50-34	6/18	
15.0									
17.5				4	SA-4	3" DO	2/1/3	0/18	
20.0				24	SA-5	3" DO	3/4/20	16/18	
	21.5								
22.5		FIRM BROWN SILT, TRACE TO LITTLE CLAY, BLACK ORGANIC MOTTLING THROUGHOUT		25	SA-6	3" DO	8-10-15	18/18	W.L.
				34	SA-7		10-16-18	18/18	
25.0	25.7			N/A	SA-8		N/A	4/6	
27.5		HARD GRAY, FINE GRAINED BIGBY CANNON LIMESTONE							
30.0									
35.0	37.0								
		BOTTOM OF BORING AT 37.0' BGS							
37.5									

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JME
DATE DRAWN 2-4-91

JOB NO. 903 3174	GA. INSP. JMF	PROJECT RCI / CSX INV / TN			BORING NO. BH-10
DEPTH HOLE 53.0	DEPTH WL. 19.2	DRILLING METHOD AIR ROTARY			SHEET 1 OF 1
TEMP 40°	TIME WL. 7:15 1/9/91	DRILLING COMPANY MILLER DRILLING			SURFACE ELEV. 598.6
WEATHER CLOUDY		DRILL RIG SCHRAM T-450		DRILLER S. PRINCE	DATUM MSL
COORDINATES N641006.6394 E1745768.6508		WT. SAMPLER HAMMER 140		DROP 30-INCHES	STARTED 2:00 1/7/91
LOCATION CSX RADNOR RAILYARD		WT. CASING HAMMER		DROP	COMPLETED 4:00 1/10/91

ELEV. DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
0.0		'FILL MATERIAL' HARD GRAY LIMESTONE BOULDER, ROCK FRAGMENTS AND GRAVEL, LITTLE TO SOME TAN TO ORANGE BROWN SILT, TRACE CLAY							
2.5			N/A	50+	SA-1	DO	25/50+ FOR 12"	4/12	
5.0									NOTE: NO DIESEL OR OIL CONTAMINATION.
7.5			N/A	50+	SA-2	DO	29/ FOR 6"	1/6	
10.0									
12.5			N/A	23	SA-3	DO	10-9-14-12	8/24	
15.0									
17.5	18.0		N/A	50+	SA-4	DO	22-15-50+	14/18	
20.0		HARD F.-M. GRAY LIMESTONE GRAVEL (LOOSE) (CAVE-IN)							W.L.
22.5									
	24.0	FIRM DK. BROWN CLAY, SOME SILT AND LS. GRAVEL							
25.0	25.0	FIRM DK. BROWN TO BLACK CLAY, SOME SILT, NO GRAVEL	CL	50+	SA-5	DO	50+ FOR 3"	0/3	
27.5	27.7		CL	14	SA-6	DO	9/5 for 9"	9/9	
30.0		HARD GRAY LIMESTONE FINE GRAINED 'BIGBY CANNON LIMESTONE							
32.5									
35.0									
37.5									
40.0									
42.5									
45.0	45.0	HARD DK. BROWN TO DK GREEN FOSSILIFEROUS HERMITAGE LIMESTONE							CHANGE IN COLOR OF CUTTINGS FROM GRAY TO DARK BROWN AT 45.0 FT BGS.
47.5									
52.5	53.0	END OF BORING AT 53.0' BGS.							

JOB NO. 903-3174	Golder Associates		CHECKED JMF
SCALE AS SHOWN			DATE DRAWN 2-4-91

2 4 0265

Boring Log

JOB NO. 903 3174 — QA. INSP. JMF — PROJECT RCI / CSX INV / TN — BORING NO. BH-11
DEPTH HOLE 59.0 — DEPTH WL 23.7 — DRILLING METHOD AIR ROTARY — SHEET 1 OF 1
TEMP 50° — TIME WL 8:00 12/4/90 — DRILLING COMPANY LAYNE ENVIRONMENTAL — SURFACE ELEV. 594.9
WEATHER RAIN — DRILL RIG GUS PECH 1000R — DRILLER J. O'BRIANT — DATUM MSL
COORDINATES N641345.6665 E.1744946.6777 — WT. SAMPLER HAMMER 140 — DROP 30" — STARTED 1:15 12/2/90
LOCATION CSX RADNOR RAILYARD — WT. CASING HAMMER — DROP — COMPLETED 12:00 12/3/90

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
0.0 – 25.5	25.5	'FILL MATERIAL' FIRM TO STIFF, DARK BROWN TO BROWN SILT, TRACE TO LITTLE CLAY, AND HARD GRAY LIMESTONE BOULDERS, ROCK FRAGMENTS AND GRAVEL.	N/A	27	SA-1	DO	26-17-10	18/18	
			N/A	42	SA-2	DO	7-14-28	16/18	NOTE: NO DIESEL OR OIL CONTAMINATION IN SOIL SAMPLES
			N/A	20	SA-3	DO	22-12-8	3/18	
			N/A	54+	SA-4	DO	7-4-50+	0/18	
									W.L
25.5 – 52.2	52.2	FIRM TO STIFF DARK BROWN SILT TRACE TO SOME CLAY, TRACE TO SOME FINE GRAVEL (LS)	ML	26	SA-5	DO	4-12-14	16/18	
			ML	22	SA-6	DO	11-11-11	4/18	
			ML	28	SA-7	DO	6-8-20	12/18	
			ML	24	SA-8	DO	8-10-14	18/18	
			ML	30	SA-9	DO	12-14-16	15/18	
52.2 – 59.0	59.0	GRAY SLIGHTLY WEATHERED FINE GRAINED LIMESTONE (BIGBY CANNON)		NA	RC-1	ROCK CORED	RQD 70%	60/60	
60.0		BOTTOM OF BORING AT 59.0' BGS							

JOB NO. 903-3174 — SCALE AS SHOWN

Golder Associates

CHECKED JMF — DATE DRAWN 2-4-91

Boring Log 24 0265

JOB NO. 203 3174	GA. INSP. JMF	PROJECT RCI / CSX INV/TN			BORING NO. BH-12
DEPTH HOLE 55.0	DEPTH WL. 30.8	DRILLING METHOD - AIR ROTARY			SHEET 1 OF 1
TEMP 35	TIME WL. 9:15 12/5/90	DRILLING COMPANY LAYNE ENVIRONMENTAL			SURFACE ELEV. 596.5
WEATHER CLEAR		DRILL RIG GUS PEACH 1000R		DRILLER T. O'BRIANT	DATUM MSL
COORDINATES N 639050.9204 E 1744480.8412		WT. SAMPLER HAMMER N/A		DROP N/A	STARTED 11:00 12/4/90
LOCATION CSX RADNOR RAILYARD		WT. CASING HAMMER		DROP	COMPLETED 5:00 12/4/90

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
	0.8	GRAY L.S. GRAVEL & ROCK FRAG.							
2.5		BIGBY CANNON LIMESTONE LIGHT GRAY, SLIGHTLY WEATHER LIMESTONE LATERAL FRACTURES, TRACE FOSSIL SHELLS.							
5.0									NOTE: NO DIESEL OR OIL CONTAMINATION
10.0									
15.0									
20.0									
25.0									
30.0	30.0	HARD, DK GREEN TO DK. BROWN, FOSSILIFEROUS LIMESTONE (HERMITAGE LS)							CHANGE IN COLOR OF CUTTINGS FROM LIGHT GRAY TO BROWN AT 30.0 FT. BGS
35.0									▼ W.L.
40.0									
45.0									
50.0									
55.0	55.0	END OF BORING AT 55.0' BGS.							

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2-4-91

Boring Log

JOB NO. 903 3174	QA. INSP. JME	PROJECT RCI / CSX INV / TN		BORING NO. BH-13	
DEPTH HOLE 9.0	DEPTH WL 4.3	DRILLING METHOD Air Rotary		SHEET 1 OF 1	
TEMP 40°	TIME WL 7:30 12/4/90	DRILLING COMPANY Layne Environmental		SURFACE ELEV. 599.5	
WEATHER Clear		DRILL RIG Gus Pech 1000R	DRILLER T. O'Bryant	DATUM MSL	
COORDINATES N 638490.9979 E 1743936.5450		WT. SAMPLER HAMMER 140	DROP 30 - Inches	STARTED 4:00 12/3/90	
LOCATION CSX Radnor Railyard		WT. CASING HAMMER	DROP	COMPLETED 4:45 12/3/90	

ELEV. DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES HAMMER BLOWS PER 6 IN.	SAMPLES REC./ATT	REMARKS
0.0		Hard gray to light gray, fine - grained Bigby Cannon Limestone							
2.5				60+	SA-1	DO	30-60 for 12"	12/12	Note: No diesel or oil contamination
5.0									
7.5				50+	SA-2	DO	50+ for 3"	3/3	
10.0		End of boring at 9.0' BGS.							

JOB NO. 903-3174	Golder Associates	CHECKED JME
SCALE As Shown		DATE DRAWN 2-4-91

Boring Log

JOB NO. 903 3174 GA. INSP. JMF PROJECT RCI/CSX INV/TN BORING NO. DT-1A
DEPTH HOLE 9.0 DEPTH WL. N/A DRILLING METHOD AUGER SHEET 1 OF 1
TEMP 60° TIME WL. N/A DRILLING COMPANY LAYNE ENVIRONMENTAL SURFACE ELEV. 586.6
WEATHER P. CLOUDY DRILL RIG GUS PECH 1000R DRILLER T. O'BRIANT DATUM MSL
COORDINATES N 640219.2454, E 1746291.4950 WT. SAMPLER HAMMER 140 DROP 30-INCHES STARTED 1:30 11/26/90
LOCATION CSX RADNOR RAILYARD WT. CASING HAMMER DROP COMPLETED 1:50 11/26/90

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES HAMMER BLOWS PER 6 IN.	SAMPLES REC./ATT	REMARKS
2.5									NOTE: LARGE RIPRAP FROM SURFACE TO 1.0 FT BGS. STRONG DIESEL ODOR ON SAMPLE SA-1.
5.0		FIRM BROWN SILT, LITTLE CLAY							
7.5									
10.0	11.0		ML	15	SA-1	DO	6-7-8-13	24/24	
12.5		END OF BORING AT 11.0 FT. BGS.							

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2-4-91

2 4 0269

Boring Log

JOB NO. 903-3174	GA. INSP. JMF	PROJECT RCI/CSL INV/TN			BORING NO. DT-1
DEPTH HOLE 29.0	DEPTH WL. 10.0	DRILLING METHOD AIR ROTARY			SHEET 1 OF 1
TEMP 65°	TIME WL. 3:45 11/20/90	DRILLING COMPANY LAYNE ENVIRONMENTAL			SURFACE ELEV. 582.5
WEATHER PT-CLDY		DRILL RIG GUS PECH 1000R	DRILLER T.O'BRIANT		DATUM MSL
COORDINATES N640715.6223 E1746290.4891		WT. SAMPLER HAMMER 140	DROP 30-inches		STARTED 9:15 11/20/90
LOCATION CSX RADNOR RAILYARD		WT. CASING HAMMER	DROP		COMPLETED 11:00 11/20/90

ELEV. DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
0.0	1.6	"TOP SOIL" SOFT DK BROWN SILT, AND HARD GRAY L.S. BOULDERS AND ROCK FRAGMENTS.							
2.5		SOFT TO FIRM, BROWN SILT, TRACE CLAY, TRACE FINE LIMESTONE GRAVEL	ML	7	SA-1	DO	3-3-4-5	14/24	
5.0									NOTE: STRONG DIESEL ODOR ON SAMPLES SA-1 THROUGH SA-3.
7.5	8.0		ML	6	SA-2	DO	2-3-3-3	24/24	
10.0									W.L.
12.5		SOFT TO FIRM, BROWN SILT, SOME FINE SAND, LITTLE CLAY, TRACE GRAVEL.	ML	6	SA-3	DO	2-3-3-5	24/24	
15.0									
17.5			ML	13	SA-4	DO	4-5-8-10	24/24	
20.0									
22.5			ML	14	SA-5	DO	2-7-7	12/18	
25.0									
27.5	26.7	HARD GRAY, FINE GRAINED BIGBY CANNON LIMESTONE							
30.0	29.0	END OF BORING AT 29.0 FT. B.G.S.							

JOB NO. 903-3174	Golder Associates	CHECKED JMF
SCALE AS SHOWN		DATE DRAWN 2-4-91

Boring Log

JOB NO. 903.5174	GA. INSP. JMF	PROJECT RCI /CSX INV / TN		BORING NO. LBH-1	
DEPTH HOLE 35.0	DEPTH WL. 27.2	DRILLING METHOD AIR ROTARY		SHEET 1 OF 1	
TEMP 60°	TIME WL. 12:00 1/17/90	DRILLING COMPANY LAYNE ENVIRONMENTAL		SURFACE ELEV. 528.6	
WEATHER PTY. CLDY		DRILL RIG GUS PECH 1000R	DRILLER T. O'BRIANT	DATUM MSL	
COORDINATES N 640850.6161 E. 1746439.7404		WT. SAMPLER HAMMER 140	DROP 30	STARTED 9:45 11/17/90	
LOCATION CSX RADNOR RAILYARD		WT. CASING HAMMER	DROP	COMPLETED 12:45 11/17/90	

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
0.0		'FILL MATERIAL'							
2.5		LOOSE TO COMPACT	N/A	2	SA-1	DO	2-11-2	12/24	NOTE: STRONG OIL ODOR IN SOIL SAMPLE SA-1
5.0		GRAY LIMESTONE BOULDERS, ROCK FRAGMENTS,	N/A	14	SA-2	DO	5-7-7-5	10/24	
		AND GRAVEL, LITTLE	N/A	6	SA-3	DO	1-2-4-5	12/24	
7.5		BROWN SILT, LITTLE CLAY, LITTLE BLACK CINDER	N/A	5	SA-4	DO	3-4-1-2	4/24	
10.0		(MED SAND GRAIN SIZE)	N/A	4	SA-5	DO	2-2-2-2	6/24	
12.5									
15.0									
17.5			N/A	4	SA-6	DO	3-4 FOR 12"	4/24	
20.0									
22.5		VOID							
25.0									
27.5	27.2								W.L
30.0		GRAY FINE GRAINED BIGBY CANNON LIMESTONE							
32.5			N/A	RQD 70%	RC-1	RC	N/A	60/60	
35.0	35.0	END OF BORING							
37.5									
40.0									

JOB NO. 903-3174	Golder Associates	CHECKED JMF	
SCALE AS SHOWN		DATE DRAWN 2-4-91	

Boring Log

JOB NO. 903-3174 GA. INSP. JMF PROJECT RCI/CSX IN/TN BORING NO. 1BH-2
DEPTH HOLE 17.0 DEPTH WL. N/A DRILLING METHOD AIR ROTARY SHEET 1 OF 1
TEMP 40° TIME WL. N/A DRILLING COMPANY LAYNE ENVIRONMENTAL SURFACE ELEV. 598.6
WEATHER CLEAR DRILL RIG GUS PECH 1000 R DRILLER T. OBRIANT DATUM MSL
COORDINATES N 640924.1013 E 1746399.6650 WT. SAMPLER HAMMER 140 DROP 30 inches STARTED 7:15 11/17/90
LOCATION CSX RADNOR RAILYARD WT. CASING HAMMER DROP COMPLETED 8:45 11/17/90

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
0.0		"FILL MATERIAL" VERY LOOSE, GRAY AND BLACK LIMESTONE GRAVEL, SOME BLACK MED. SIZE CINDER							
2.5			N/A	2	SA-1	DO	1-1-1-1	4/24	NOTE: STRONG OIL ODOR IN SAMPLE SA-1.
		"FILL MATERIAL" SOFT BROWN CLAY, SOME SILT, AND GRAY LIMESTONE BOULDERS ROCK FRAGMENTS, AND GRAVEL.	N/A	9	SA-2	DO	4-2-7-8	12/24	
5.0			N/A	9	SA-3	DO	4-5-4-3	4/24	
7.5			N/A	5	SA-4	DO	6-1-4-12	5/24	
10.0			N/A	12	SA-5	DO	5-7-5-6	5/24	
12.5									
15.0			N/A	4	SA-6	DO	4-3-1-7	4/24	
17.5	17.0	END OF BORING AT 17.0 FT. BGS.							

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 7-4-91

Boring Log

JOB NO. 903 3174	GA. INSP. JMF	PROJECT RCI / CSX INV / TN			BORING NO. LBH-3
DEPTH HOLE 35.0	DEPTH WL. 24.7	DRILLING METHOD AIR ROTARY			SHEET 1 OF 1
TEMP 70°	TIME WL. 2:20 11/20	DRILLING COMPANY LAYNE ENVIRONMENTAL			SURFACE ELEV. 598.6
WEATHER CLEAR		DRILL RIG GUS PECH 1000R		DRILLER J. O'BRANT	DATUM MSL
COORDINATES N640832.5516 E. 1746404.6947		WT. SAMPLER HAMMER N/A		DROP N/A	STARTED 1:15 11/20/90
LOCATION CSX RADNOR RAILYARD		WT. CASING HAMMER		DROP	COMPLETED 2:15 11/20/90

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES HAMMER BLOWS PER 6 IN.	SAMPLES REC./ATT	REMARKS
0.0		GREY L.S. GRAVEL COBBLES WITH BLACK CINDER							
5.0		'FILL MATERIAL' LARGE COBBLES AND GRAVEL (L.S.) WITH BROWN SILTY CLAY MATRIX							NOTE: NO SOIL SAMPLING BOREHOLE DRILLED TO CHECK FOR VOIDS AND TOP OF BEDROCK
10.0									
15.0									
	19.0								
20.0		L.S. BOULDER							
	21.0								
	21.4	VOID							
	23.8	L.S. BOULDER							
	24.8	VOID							W.L.
25.0	25.6	L.S. BOULDER							
	27.8	SOFT TO FIRM CLAYEY SILT OR SILTY CLAY	L.S. OR	BOULDER LEDGE					
30.0		SOFT TO FIRM CLAYEY SILT OR SILTY CLAY							
	32.1								
	32.6	L.S. BEDROCK							
		VOID	VOID						
	32.9	HARD GRAY BIGBY CANNON LIMESTONE							
35.0	35.0								
		BOTTOM OF BORING AT 35.0' BGS							

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2-4-91

APPENDIX C

PIEZOMETER INSTALLATION LOGS

APPENDIX D

HYDRAULIC CONDUCTIVITY TEST DATA AND ANALYSES

RESOURCE CONSULTANTS

Golder Associates	SUBJECT RC/CSX Inv/TN		
	Job No. 903-3174	Made by JMF	Date 2/14/91
	Ref.	Checked	Sheet 1 of 1
		Reviewed	

PIEZOMETER P-4

$K = \frac{1.0\, r_c^2}{(b)t_1}$

$r_c = 0.083$
$b = 15.0$
$t_1 = 11.5\text{ min}$

$K = \frac{1.0\,(0.083)^2}{(15.0)11.5\text{ min}} = 3.99 \times 10^{-5}\text{ ft/min}$

$K = 2.03 \times 10^{-5}\text{ cm/s}$

PIEZOMETER P-1

$r_c = 0.083$
$b = 5.0$
$t_1 = 38.0\text{ min}$

$K = \frac{1.0\,(0.083)^2}{5\,(38.0\text{ min})} = 3.63 \times 10^{-5}\text{ ft/min}$

$K = 1.84 \times 10^{-5}\text{ cm/s}$

PIEZOMETER P-2

$r_c = 0.083$
$b = 10.0$
$t_1 = 0.5\text{ min}$

$K = \frac{1.0\,(0.083)^2}{10\text{ft}\,(.11\text{ min})} = 6.26 \times 10^{-3}\text{ ft/min}$

$= 3.18 \times 10^{-3}\text{ cm/s}$

Piezometer P-3

$r_c = 0.083$
$b = 20.0$

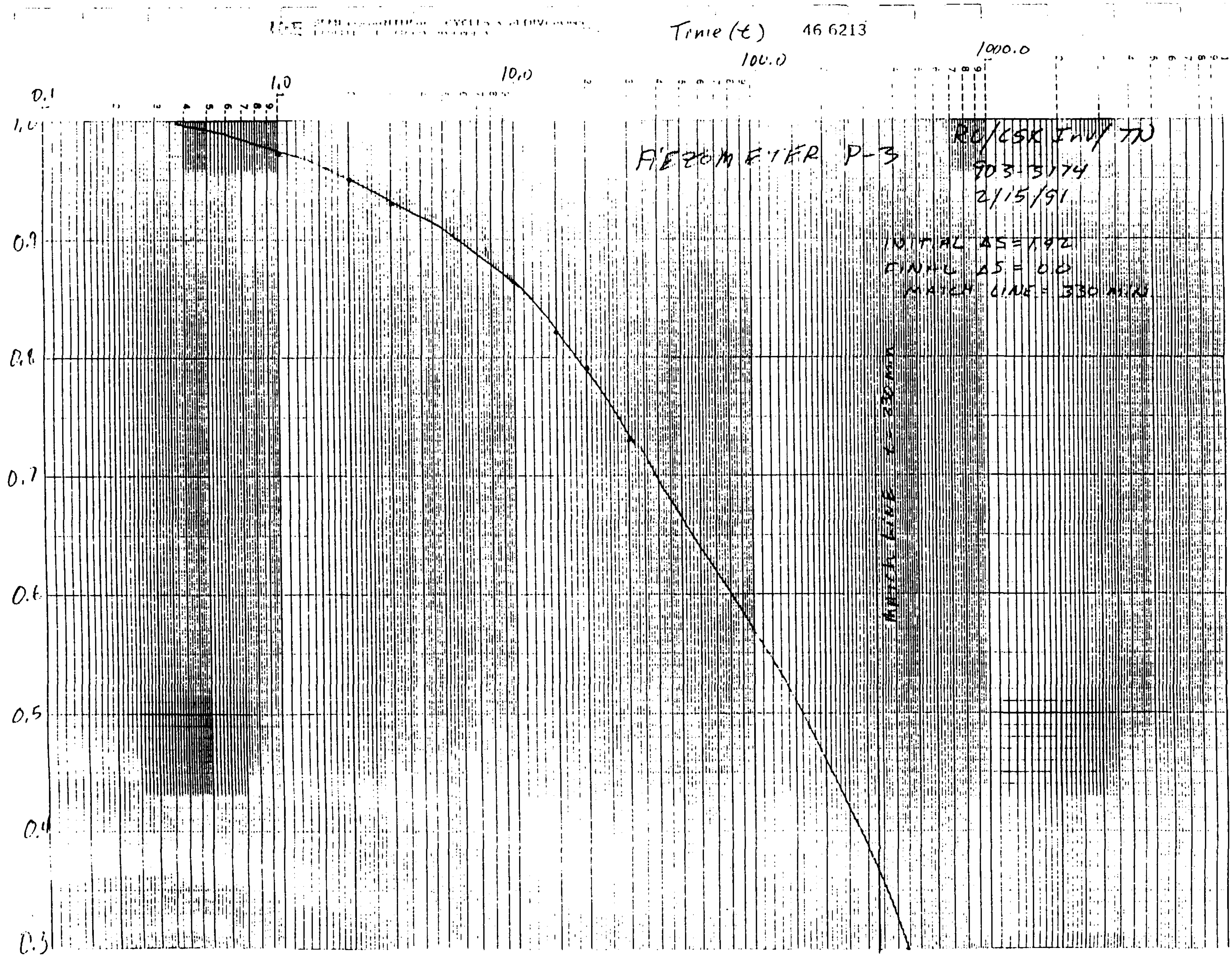
$K = \frac{1.0\,(0.083)^2}{20\text{ft}\,(330\text{ min})} = 5.30 \times 10^{-7}\text{ cm/s}$

ASSUMING AN AV. (K) for Piezometers P-1, P-2 and P-4
GEOMETRIC MEAN $= ((2.03 \times 10^{-5})(1.84 \times 10^{-5})(3.18 \times 10^{-3}))^{1/3}$

$\bar{K} = 1.06 \times 10^{-4}\text{ cm/s}$

$\bar{V} = \frac{K\,dh/dl}{n_e}$ $\quad \bar{V} = \frac{(1.06 \times 10^{-4}\text{ cm/s})\,(0.012)}{(0.01)} = 1.27 \times 10^{-4}\text{ cm/s}$

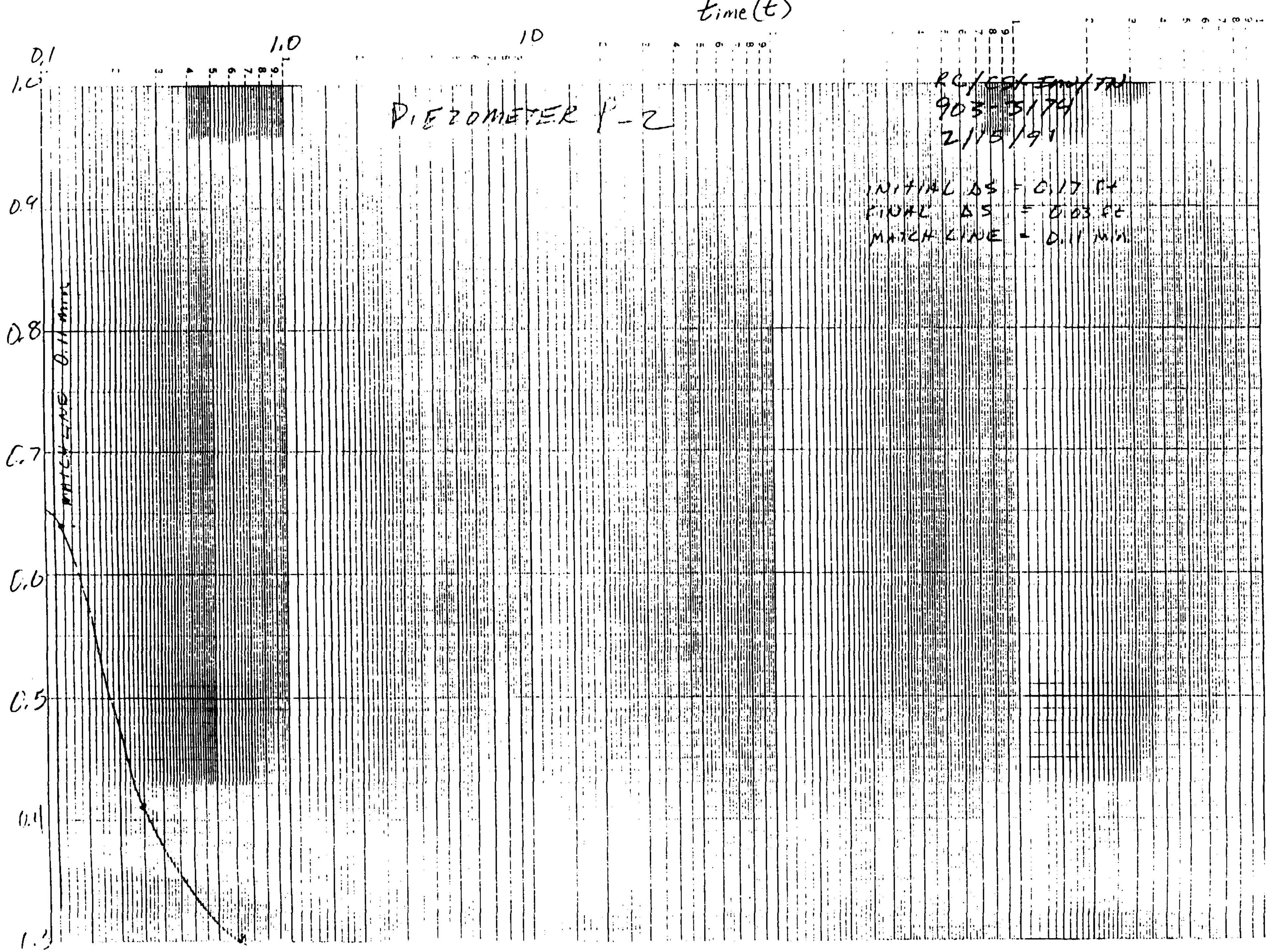
The Average velocity $\bar{V} = 132$ ft/yr
40.1 m/yr

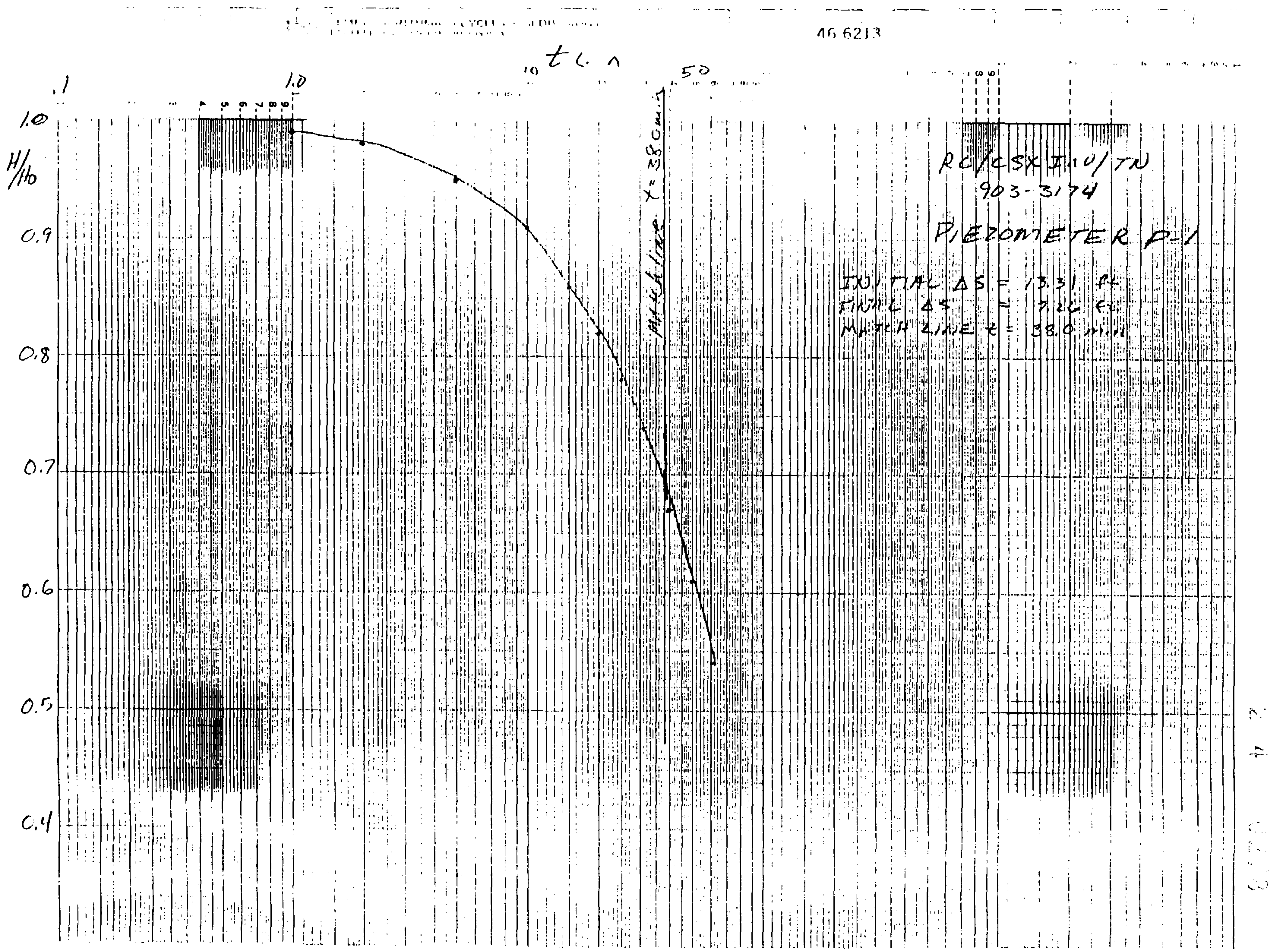


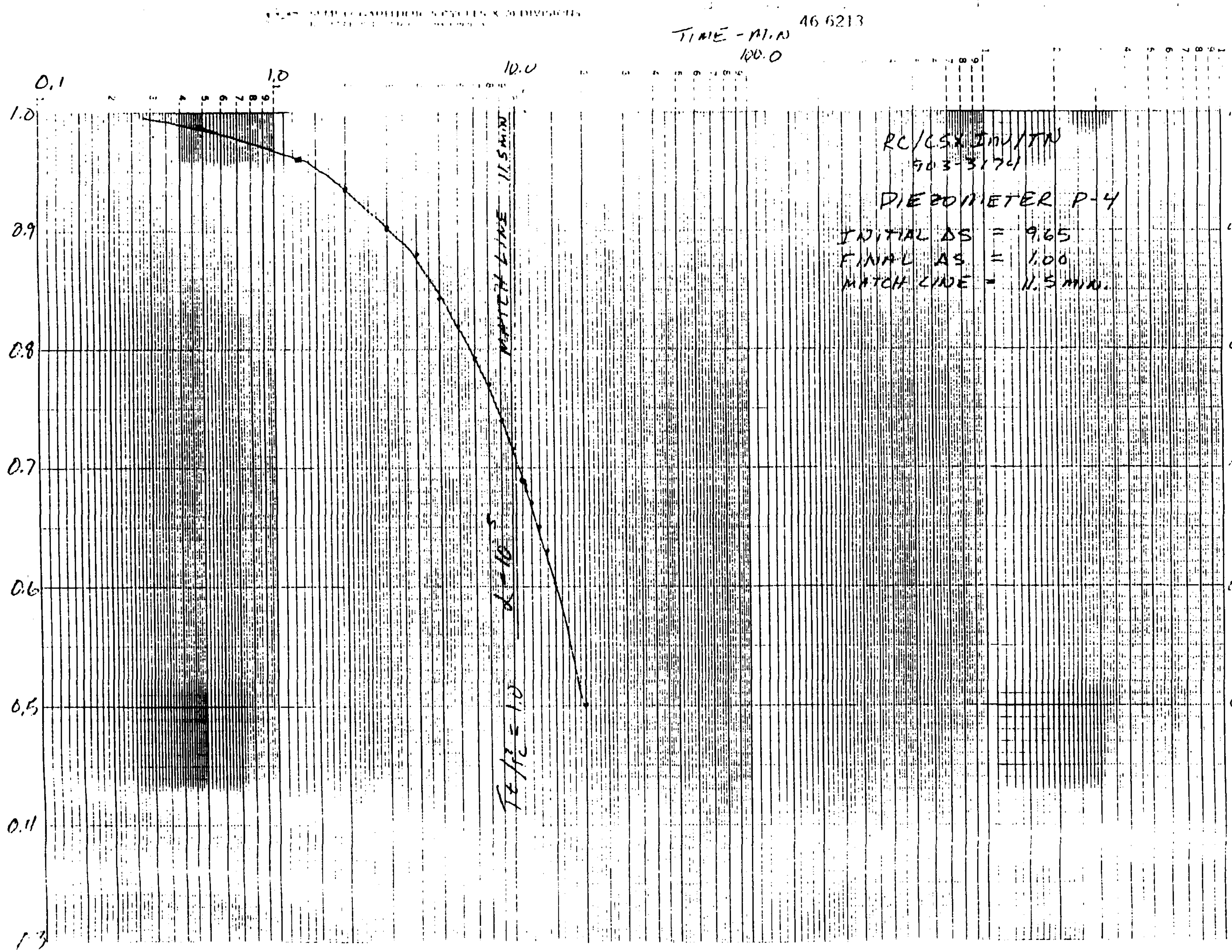
Time (t)
46 6213
0.1
1.0
10.0
100.0
1000.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
PIEZOMETER P-3
RC/CSK Inv/ TN
903-3174
2/15/91
INITIAL ΔS = 1.92
FINAL ΔS = 0.0
MATCH LINE = 330 MIN.
MATCH LINE t = 330 min

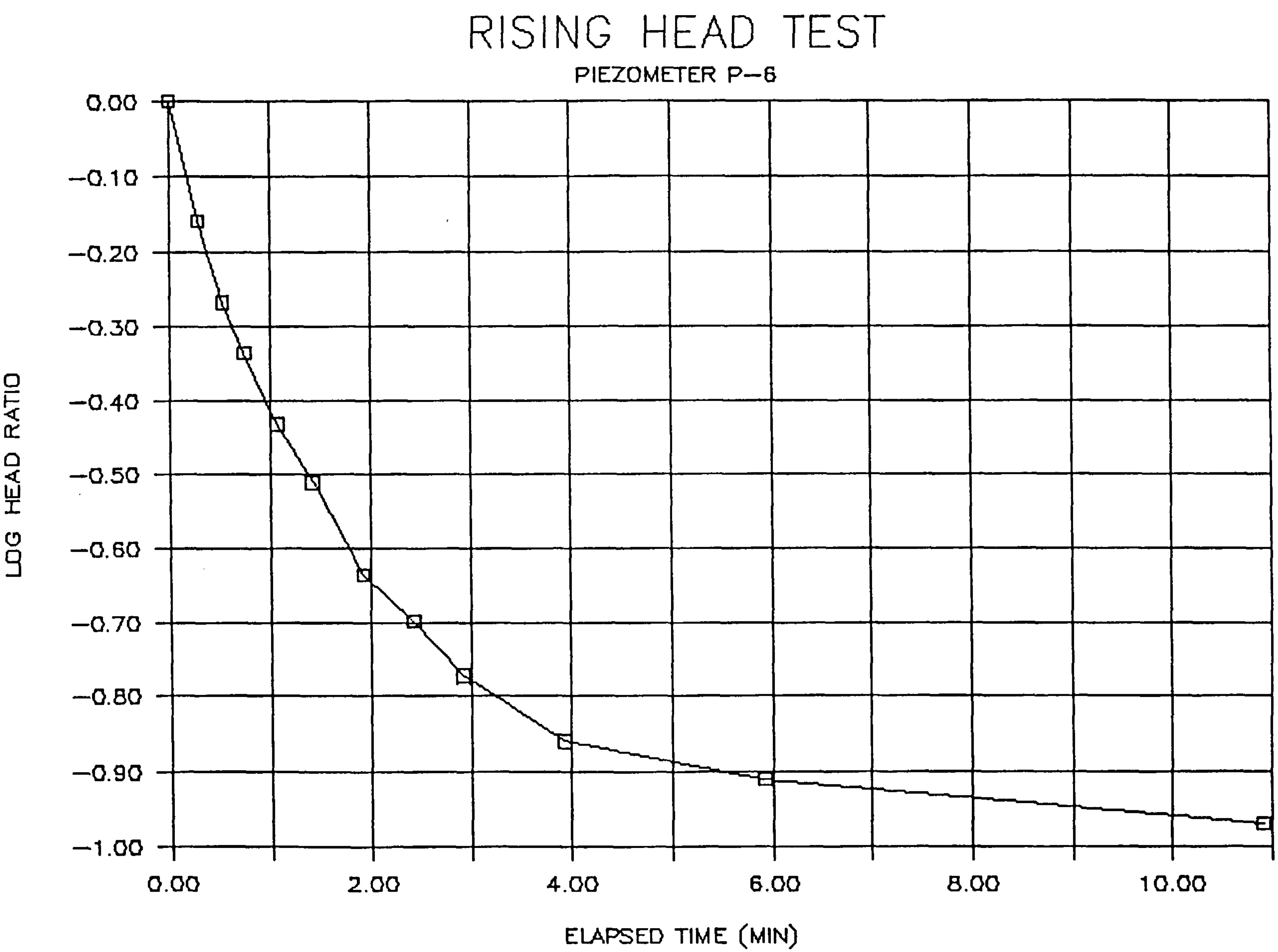
24 0276

46 6213


time (t)
0.1
1.0
10
1.0
0.9
0.8
0.7
0.6
0.5
0.4
PIEZOMETER P-2
RC/CSX EMY/TN
903-5174
2/15/91
INITIAL ΔS = 0.17 ft
FINAL ΔS = 0.03 ft
MATCH LINE = 0.11 MIN
MATCHING LINE 0.11 MIN


46 6213
t (min)
H/Ho
1.0
0.9
0.8
0.7
0.6
0.5
0.4
.1
1.0
10
50
Match line t = 38.0 min
RC/CSX I-10/TN
903-3174
PIEZOMETER P-1
INITIAL ΔS = 13.31 ft
FINAL ΔS = 7.26 ft
MATCH LINE t = 38.0 min


46 6213
TIME - MIN
0.1
1.0
10.0
100.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
MATCH LINE 11.5 MIN
$\lambda = 10^5$
$T_t/T_c = 1.0$
RC/CSX INV/TN
903-3174
PIEZOMETER P-4
INITIAL ΔS = 9.65
FINAL ΔS = 1.00
MATCH LINE = 11.5 MIN.


RISING HEAD TEST
PIEZOMETER P-6
LOG HEAD RATIO
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
-0.70
-0.80
-0.90
-1.00
0.00
2.00
4.00
6.00
8.00
10.00
ELAPSED TIME (MIN)

2 4

FEBRUARY, 1991 903-3174

RISING HEAD TEST

PIEZOMETER P-6

STATIC WATER DEPTH= 14.10 FEET BELOW TOC
STANDPIPE DIAMETER= 2.00 INCHES
SANDPACK DIAMETER= 8.000 INCHES
TOP OF SATURATED SAND= 13.10 FEET BELOW TOC
BOTTOM OF SANDPACK= 25.50 FEET BELOW TOC

HOUR	MIN	SEC	ELAPSED TIME (MIN)	DEPTH TO WATER (FT TOC)	HEAD (FEET)	HEAD RATIO (H/Ho)	LOG HEAD RATIO
		0	0.0000	14.75	-0.65	1.000	0.0000
		17	0.2833	14.55	-0.45	0.692 *	-0.1597
		32	0.5333	14.45	-0.35	0.538	-0.2688
		45	0.7500	14.40	-0.30	0.462 *	-0.3358
	1	4	1.0667	14.34	-0.24	0.369	-0.4327
	1	25	1.4167	14.30	-0.20	0.308	-0.5119
	1	55	1.9167	14.25	-0.15	0.231	-0.6368
	2	25	2.4167	14.23	-0.13	0.200	-0.6990
	2	55	2.9167	14.21	-0.11	0.169	-0.7715
	3	55	3.9167	14.19	-0.09	0.138	-0.8587
	5	55	5.9167	14.18	-0.08	0.123	-0.9098
	10	55	10.9167	14.17	-0.07	0.108	-0.9678

* INDICATES THE BEST FIT LINE PASSES THROUGH THESE POINTS
WHICH ARE USED TO CALCULATE HYDRAULIC CONDUCTIVITY

K= 4.47E-04 CM/SEC

Boring Log

JOB NO.	903 3174	QA. INSP.	JMF	PROJECT	RCI/CSX INV/TN	BORING NO.	P-5
DEPTH HOLE	58.0	DEPTH WL.	N/A	DRILLING METHOD	AIR ROTARY	SHEET	1 OF 1
TEMP	50°	TIME WL.	N/A	DRILLING COMPANY	MILLER DRILLING	SURFACE ELEV.	596.3
WEATHER	RAIN / CLOUDY	DRILL RIG	SCHRAM T-450	DRILLER	D. PRICE	DATUM	MSL
COORDINATES	N 641456.4280 E 1744623.6101	WT. SAMPLER HAMMER	14	DROP	30	STARTED	12:45 12/18/90
LOCATION	CSX RADNOR RAILYARD	WT. CASING HAMMER		DROP		COMPLETED	10:45 12/19/90

ELEV. / DEPTH	DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
2.5								
5.0								NOTE: SEE BOREHOLE LOG P-4 FOR DETAILS FROM SURFACE TO 40.0 FT BGS.
7.5								
10.0								
12.5								
15.0								
17.5								
20.0								
22.5								
25.0	'FILL MATERIAL'							
27.5	FIRM BROWN SILT, LITTLE TO SOME CLAY, AND, GRAY LIMESTONE ROCK FRAGMENTS, GRAVEL, LITTLE FINE SAND							
30.0								
32.5								
35.0								NOTE: NO DIESEL ODOR PRESENT IN SAMPLES SA-1 THROUGH SA-3.
37.5								NO WATER IN BOREHOLE OBSERVED
40.0		N/A	N/A	SA-1	DO	PUSHED	0/24	
42.5								
45.0		N/A	N/A	SA-2	DO	PUSHED	6/24	NOTE: FROM 48.0 TO 58.0 FT BGS. FINE TO MEDIUM LIMESTONE GRAVEL. STORM SEWER IS ADJACENT TO BORING
47.5								
50.0		N/A	N/A	SA-3	DO	PUSHED	3/24	
52.5								
55.0								
57.5 / 58.0	END OF BORING AT 58.0 FT. BGS.							
60.0								

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2-4-91

2 4 0203

Boring Log

JOB NO. 903 3742 GA. INSP. JMF PROJECT RCI/CSX INV/TN BORING NO. P-6
DEPTH HOLE 27.5 DEPTH WL. 11 BG DRILLING METHOD AIR ROTARY/AIR HAMMER SHEET 1 OF 1
TEMP 35° TIME WL. 11:00 1/10/91 DRILLING COMPANY MILLER DRILLING SURFACE ELEV. 592.3
WEATHER CLOUDY DRILL RIG SCHRAM T-450 DRILLER S. PRINCE DATUM MSL
COORDINATES N 639754.5572 E 1745355.0021 WT. SAMPLER HAMMER 140 DROP 30-INCHES STARTED 8:30 1/3/91
LOCATION CSX RADNOR RAILYARD WT. CASING HAMMER DROP COMPLETED 5:30 1/3/91

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES HAMMER BLOWS PER 6 IN.	SAMPLES REC./ATT	REMARKS
2.5		'FILL MATERIAL' HARD GRAY LIMESTONE BOULDERS, ROCK FRAGMENTS, AND GRAVEL, LITTLE BROWN SILT, LITTLE CLAY	N/A	53	SA-1	OO	12-18-35	14/18	
5.0	6.0								NOTE: NO DIESEL OR OIL CONTAMINATION IN SOIL SAMPLES
7.5		FIRM TO STIFF ORANGE BROWN TO TAN SILT, LITTLE TO AND CLAY, TRACE RIVER WASHED F. GRAVEL	ML	33	SA-2	OO	9-12-21-21	21/24	
10.0									
12.5									W.L.
15.0									
17.5			ML	26	SA-3	OO	10-16-10-14	18/18	
20.0									
22.5			ML	32	SA-4	OO	12-14-18-14	24/24	
25.0									
27.5	27.5	END OF BORING AT 27.5 FT. BGS HARD GRAY, FINE GRAINED BIGBY CANNON LIMESTONE		15	SA-5	OO	9-6-9	18/18	
30.0									
32.5									
35.0									
37.5									
40.0									
42.5									
45.0									

JOB NO. 903-3742 SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2-4-91

MONITORING WELL INSTALLATION LOG

JOB NO. 903-3174	PROJECT RCI/CSX INV/TN	WELL NO. P-1	SHEET 1 1
GA INSP. JMF	DRILLING METHOD AIR ROTARY/AIR HAMMER	GROUND ELEV. 600.2	WATER DEPTH 25.23
WEATHER CLDY	DRILLING COMPANY MILLER DRILLING	COLLAR ELEV. 600.20	DATE/TIME 1/18/91 11:45
TEMP. 40	DRILL RIG SCHRAM T-450 DRILLER STEVE PRINCE	STARTED 2:45 12/27/90 (TIME / DATE)	COMPLETED 4:00 1/4/91 (TIME / DATE)

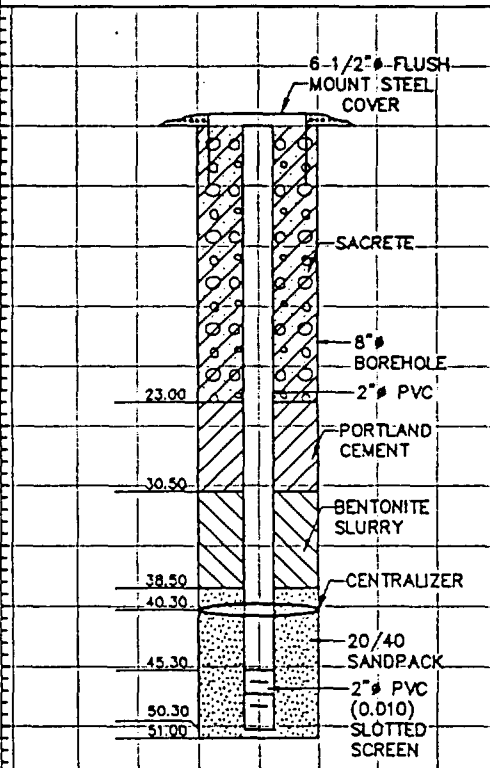
LOCATION / COORDINATES N641526.3046 E1745955.6199

MATERIALS INVENTORY

WELL CASING 2.0 in. dia. 45.0 l.f.	WELL SCREEN 2.0 in. dia. 5.0 l.f.	BENTONITE SEAL BENTONITE SLURRY
CASING TYPE PVC	SCREEN TYPE SLOTTED PVC	INSTALLATION METHOD TREMIE
JOINT TYPE FLUSH	SLOT SIZE (0.010)	FILTER PACK QTY. 2.5 BAGS
GROUT QUANTITY 4 BAGS / 9.5 BAGS	CENTRALIZERS 1	FILTER PACK TYPE 20/40 SAND
GROUT TYPE PORTLAND/SACRETE	DRILLING MUD TYPE N/A	INSTALLATION METHOD TREMIE

ELEV./DEPTH	SOIL/ROCK DESCRIPTION
	GROUND SURFACE
0.0 – 24.40	"Fill Material" Stiff brown SILT, some clay, and gray fine grained limestone boulders, rock fragments and gravel.
24.40 – 32.40	Firm reddish brown to brown SILT, little to some clay, some ls fine gravel, (Moist).
32.40 – 51.00	Hard, light gray, to gray, fine grained "Bigby Cannon Limestone".

WELL SKETCH



INSTALLATION NOTES

POURED 1/3 GAL. OF SAND FROM 51.0 TO 50.3 FT. BGS. SET 5.0' OF SCREEN AND 45.0' OF PVC RISER AT 50.3 FT. BGS. TREMIED 20/40 SAND FROM 50.3 TO 38.5 FT. BGS. TREMIED 30 GAL. OF BENTONITE SLURRY FROM 38.5 TO 30.5 FT. BGS. 12/29/90. TREMIED 4 BAGS (40 GAL) OF PORTLAND CEMENT FROM 30.5 TO 23.0 FT. BGS. 1/4/90. POURED 9.5 BAGS OF SACRETE FROM 23.0 TO SURFACE AND SET 6 1/2" STEEL FLUSH MOUNT COVER.

WELL DEVELOPMENT NOTES

SEE ATTACHED WELL DEVELOPMENT RECORD

WELL DEVELOPMENT FIELD RECORD

JOB NAME RC/SX Inv/ TN JOB NO. 903-3174.2 WELL NO. P-1

DEVELOPED BY JMF DATE OF INSTALL 12/1/90 12/28/90 SHEET 1 OF 1

STARTED DEVEL. 12/4/90 / 8:00 (DATE / TIME) COMPLETED DEVEL. 2-7-91 / 12:30Am (DATE / TIME)

W.L. BEFORE DEVEL. 25.69 / 2-7-91 / 10:55 (DEPTH / DATE / TIME) AFTER DEVEL. 32.95 / 2-7-91 / 12:30 (DEPTH / DATE / TIME)

WELL DEPTH: BEFORE DEVEL. 50.3 AFTER DEVEL. 51.0 WELL DIA. (in) 2.0

STANDING WATER COLUMN (FT.) 24.61 STANDING WELL VOLUME 12 gal.

SCREEN LENGTH 5.0 DRILLING WATER LOSS NONE gal.

DATE/TIME	VOLUME REMOVED (GALS)	FIELD PARAMETERS SPEC. COND. (umhos/cm)	TEMP. (C°)	pH (s.u.)	OTHER	REMARKS
12/4/90 8:00	35	200	15.1	7.20	—	mod. Turbid
						NOTE: redrilled
						from 45 to 51.0 ft BGS
2-7-91 11:00	45	63	14.4	7.33	—	mod turbid
2-7-91-12:00	20	64	14.6	7.50	—	slightly turbid
2-7-91-12:30	20	60	14.6	7.48	—	slightly turbid
	79.5	= TOTAL VOLUME REMOVED (gal.)				

DEVELOPMENT METHOD: Manual bailing

NOTE: High conductance on 12/4/90 due to screening of silt layer. lower conductance on 2/7/91 because the screen is within the limestone rock.

NOTES:

MONITORING WELL INSTALLATION LOG

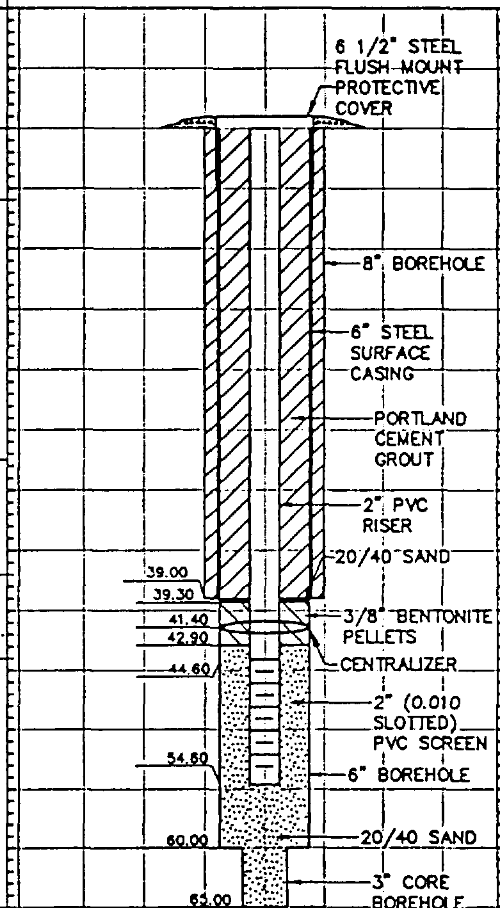
JOB NO. 903-3174 PROJECT RCI/CSX INV/TN WELL NO. P-2 SHEET 1 1
GA INSP. JMF DRILLING METHOD AIR HAMMER/AIR ROTARY/CORE GROUND ELEV. 592.3 WATER DEPTH 13.10
WEATHER RAIN DRILLING COMPANY MILLER DRILLING COLLAR ELEV. 592.24 DATE/TIME 1/9/91 11:30
TEMP. 45° DRILL RIG SCHRAM T-450 DRILLER STEVE PRINCE STARTED 3:30 1/9/91 (TIME / DATE) COMPLETED 11:15 1/10/91 (TIME / DATE)
LOCATION / COORDINATES N639800.8991 E1745397.7713

MATERIALS INVENTORY

WELL CASING 2.0 in. dia. 44.0 l.f. WELL SCREEN 2.0 in. dia. 10.0 l.f. BENTONITE SEAL 3/8" PELLETS
CASING TYPE PVC SCREEN TYPE PVC INSTALLATION METHOD POURED
JOINT TYPE FLUSH SLOT SIZE 0.010 FILTER PACK QTY. 3 BAGS
GROUT QUANTITY 50 GAL /5 1/2 BAGS CENTRALIZERS 1 FILTER PACK TYPE 20/40 SAND
GROUT TYPE PORTLAND / SACRETE DRILLING MUD TYPE N/A INSTALLATION METHOD TREMIE

ELEV./DEPTH	SOIL/ROCK DESCRIPTION
	GROUND SURFACE
0.0 – 6.0	"Fill Material" Hard gray limestone boulders, little brown silt.
6.0 – 27.50	Soft to firm, orange brown to tan SILT, little to and clay, trace river washed gravel.
27.50 – 37.00	Void in "Bigby Limestone" (Possibly on cliff face).
37.00 – 44.00	Hard gray, fine grained "Bigby Cannon Limestone".
44.00 – 65.00	Hard dark brown to dark green fossiliferous "Hermitage Limestone".

WELL SKETCH



INSTALLATION NOTES

(3:30 1/9/91) TREMIED SAND FROM 65.0 TO 54.6 FT. BGS. SET 10 FT. OF (0.010 SLOTTED) PVC SCREEN AND 44.6 FT. OF RISER AT 54.6 FT. BGS. TREMIED 2 1/2 BAGS OF 20/40 SAND FROM 54.6 TO 42.9 FT. BGS. POURED (1) 5 GAL. BUCKET OF BENTONITE 3/8" PELLETS FROM 42.9 TO 39.3 FT. BGS. POURED 1/5 OF A BAG OF 20/40 SAND FROM 39.3 TO 39.0 FT. BGS. TREMIED 50 GAL. OF PORTLAND CEMENT FROM 39.0 TO 0.5 FT. BGS. SET 6 1/2" STEEL FLUSH MOUNT COVER W/ 5 1/2 BAGS SACRETE.

WELL DEVELOPMENT NOTES

SEE ATTACHED WELL DEVELOPMENT RECORD

WELL DEVELOPMENT FIELD RECORD

JOB NAME RCI/CSX Inv/TN JOB NO. 903-3174.2 WELL NO. P-2

DEVELOPED BY JMF DATE OF INSTALL 1/10/91 SHEET 1 OF 1

STARTED DEVEL. 1/16/91 (DATE) / 1:10 (TIME) COMPLETED DEVEL. 1/16/91 (DATE) / 2:50 (TIME)

W.L. BEFORE DEVEL. 15.07 (DEPTH) / 1/16/91 (DATE) / 1:10 (TIME) AFTER DEVEL. ~~[illegible]~~ 16.90 (DEPTH) / 1/16/91 (DATE) / 2:50 (TIME)

WELL DEPTH: BEFORE DEVEL. 54.6 AFTER DEVEL. 54.6 WELL DIA. (In) 2.0

STANDING WATER COLUMN (FT.) 40.53 STANDING WELL VOLUME 9.85 gal.

SCREEN LENGTH 10.0 DRILLING WATER LOSS N/A gal.

DATE/TIME	VOLUME REMOVED (GALS)	FIELD PARAMETERS SPEC. COND. (umhos/cm)	TEMP. (C°)	pH (s.u.)	OTHER	REMARKS
1/16/91 2:25	45	590	15.6	6.79		slightly turbid
1/16/91 2:40	50	600	15.0	7.10		clear
1/16/91 2:50	60	600	15.4	7.06		clear
	60	= TOTAL VOLUME REMOVED (gal.)				

DEVELOPMENT METHOD: Arch well pump

NOTES:

Z 4 0283

MONITORING WELL INSTALLATION LOG

JOB NO. 903-3174	PROJECT RCI/CSX INV/TN	WELL NO. P-3	SHEET 1 1
GA INSP. JMF	DRILLING METHOD AIR ROTARY/AIR HAMMER	GROUND ELEV. 595.5	WATER DEPTH 82.03
WEATHER CLDY	DRILLING COMPANY LAYNE ENV/MILLER DRILLING	COLLAR ELEV. 595.60	DATE/TIME 12/19/90 3:10
TEMP. 45°	DRILL RIG GUS PECH 1000R / DRILLER TOM OBRIANT	STARTED 3:10 12/19/90 (TIME / DATE)	COMPLETED 11:30 12/21/90 (TIME / DATE)

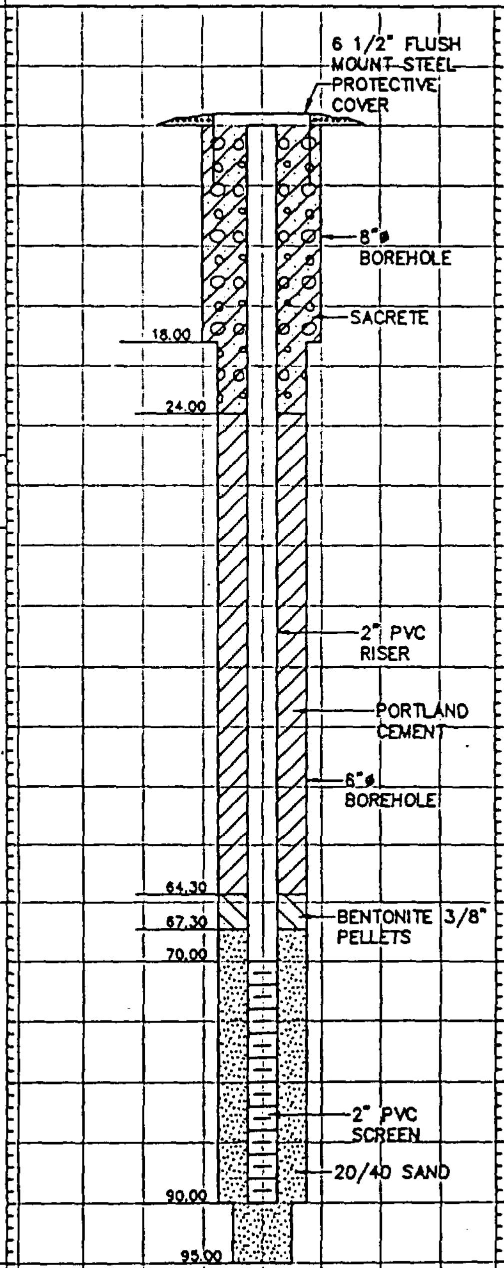
LOCATION / COORDINATES N640609.4038,E1744283.4466

MATERIALS INVENTORY

WELL CASING 2.0 in. dia. 70.0 L.f.	WELL SCREEN 2.0 in. dia. 20.0 L.f.	BENTONITE SEAL 1/5 GAL. 3/8" PELLETS
CASING TYPE PVC	SCREEN TYPE SLOTTED PVC	INSTALLATION METHOD POURED
JOINT TYPE FLUSH	SLOT SIZE 0.010	FILTER PACK QTY. 3 BAGS
GROUT QUANTITY 8 BAGS / 28 BAGS	CENTRALIZERS N/A	FILTER PACK TYPE 20/40 SAND
GROUT TYPE PORTLAND/SACRETE	DRILLING MUD TYPE N/A	INSTALLATION METHOD TREMIED

ELEV./DEPTH	SOIL/ROCK DESCRIPTION
	GROUND SURFACE
0.0	"Fill Material" Stiff brown SILT, and fine SAND, and gray limestone boulders, rock fragments, and gravel, little clay.
27.50	Stiff brown to reddish brown, SILT, trace clay, trace river washed fine gravel.
33.50	Hard, gray, fined grained "Bigby Cannon Limestone".
65.00	Hard dark gray to dark green fossiliferous "Hermitage Limestone".
95.00	

WELL SKETCH



INSTALLATION NOTES

3:10 12/19/90 REMOVED TEMPORARY PVC SCREEN AND RISER FROM OPEN BOREHOLE. 5:30 SET 20.0' OF (0.010) SCREEN FROM 90.0 TO 70.0 FT. BGS AND 70.0 FT. OF RISER TO SURFACE. TREMIED 20/40 SAND FROM 95.0 TO 67.3 FT. BGS. POURED 5 GAL. OF BENTONITE PELLETS FROM 67.5 TO 64.3 FT. BGS. 6:00 12/20/90 PUMPED 8 BAGS OF PORTLAND CEMENT FROM 64.3 TO 24.0 FT. BGS. 11:00 12/21/90 POURED 28 BAGS OF SACRETE FROM 24.0 TO SURFACE AND SET 6 1/2" FLUSHMOUNT STEEL PROTECTIVE COVER.

NOTE: WATER LEVEL ON 12/19/90 IS HIGH DUE TO ADDED WATER DURING WELL INSTALLATION.

WELL DEVELOPMENT NOTES

SEE ATTACHED WELL DEVELOPMENT RECORD

WELL DEVELOPMENT FIELD RECORD

JOB NAME RCI/CSX Inv/TN JOB NO. 903-3174.2 WELL NO. P-3

DEVELOPED BY JMF DATE OF INSTALL 12/21/90 SHEET 1 OF 1

STARTED DEVEL. 12/15/90 / 10:45 (DATE / TIME) COMPLETED DEVEL. 1/18/91 / 9:09 (DATE / TIME)

W.L. BEFORE DEVEL. 81.44 / 1/18/91 / 9:09 (DEPTH / DATE / TIME) AFTER DEVEL. 33.61 / 12/15/91 / 1:10 (DEPTH / DATE / TIME)

WELL DEPTH: BEFORE DEVEL. 90.0 AFTER DEVEL. 90.0 WELL DIA. (in) 2.0

STANDING WATER COLUMN (FT.) 8.56 STANDING WELL VOLUME 3.77 gal.

SCREEN LENGTH 20.0 DRILLING WATER LOSS N/A gal.

DATE/TIME	VOLUME REMOVED (GALS)	FIELD PARAMETERS SPEC. COND. (umhos/cm)	TEMP. (C°)	pH (s.u.)	OTHER	REMARKS
12/15/90 10:45	15	—	—	—	—	(open hole) Slightly Turbid
1/9/91 9:50	25	1000	15.0	7.25	—	
1/9/91 10:10	30	1600	15.2	7.20		
1/18/91 9:09	35	1400	14.6	7.20		
	35	= TOTAL VOLUME REMOVED (gal.)				

DEVELOPMENT METHOD: Manual bailing

NOTES:

2 4 0229

MONITORING WELL INSTALLATION LOG

JOB NO. 903-3174	PROJECT RCI/CSX INV/TN	WELL NO. P-4	SHEET 1 1
GA INSP. JMF	DRILLING METHOD AIR ROTARY	GROUND ELEV. 596.6	WATER DEPTH 39.94
WEATHER P CLDY/RAIN	DRILLING COMPANY LAYNE ENVIRONMENTAL	COLLAR ELEV. 596.59	DATE/TIME 12/13/90 9:55
TEMP. 45°	DRILL RIG GUS PECH 1000R / DRILLER TOM OBRIANT	STARTED 7:15 12/12/90 (TIME / DATE)	COMPLETED 8:00 12/15/90 (TIME / DATE)

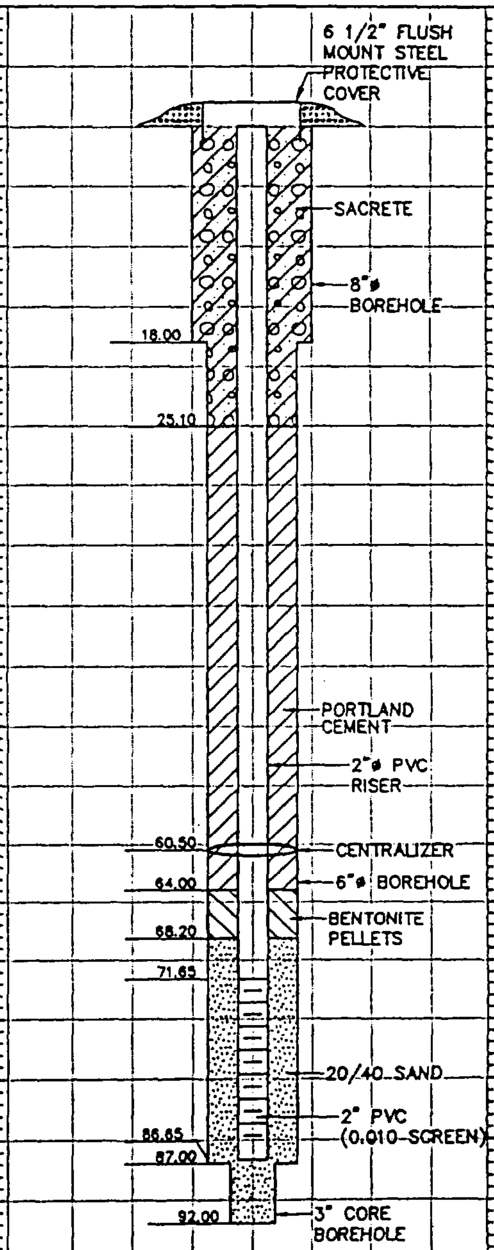
LOCATION / COORDINATES N641465.9333,E1744632.0200

MATERIALS INVENTORY

WELL CASING 2.0 in. dia. 71.65 l.f.	WELL SCREEN 2.0 in. dia. 15.0 l.f.	BENTONITE SEAL BENTONITE 3/8" PELLETS
CASING TYPE PVC	SCREEN TYPE SLOTTED PVC	INSTALLATION METHOD POURED
JOINT TYPE FLUSH	SLOT SIZE (0.010)	FILTER PACK QTY. 2 BAGS
GROUT QUANTITY 4 BAGS / 40 BAGS	CENTRALIZERS (1)	FILTER PACK TYPE 20/40 SAND
GROUT TYPE PORTLAND / SACRETE	DRILLING MUD TYPE N/A	INSTALLATION METHOD TREMIE

ELEV./DEPTH	SOIL/ROCK DESCRIPTION
	GROUND SURFACE
0.0 – 1.80	Compact, gray fine to med. limestone gravel, little silt.
1.80 – 41.00	"Fill Material" Firm to very stiff brown SILT, little to and clay, and gray, fine grained limestone boulders, rock fragments, and gravel.
41.00 – 57.50	Stiff to very stiff dark brown SILT, trace to little clay, trace fine river washed gravel. Gray and orange brown mottled SILT 57.0–57.5.
57.50 – 67.50	Hard gray fine grained "Bigby Cannon Limestone".
67.50 – 92.00	Hard dark green to dark brown, fossiliferous "Hermitage Limestone".

WELL SKETCH



INSTALLATION NOTES

12/12/90 7:30 TREMIED SAND FROM 92.0 TO 86.65. SET 2" PVC WELL FROM 86.65 TO SURFACE, WITH 2" PVC SCREEN FROM 86.65 TO 71.65 FT. BGS. TREMIED 20/40 SAND FROM 86.65 TO 68.2 FT. BGS. POURED 1 BUCKET OF BENTONITE PELLETS FROM 68.2 TO 64.0 FT. BGS. 9:30 – TREMIED 4 BAGS OF PORTLAND (50 GAL.) FROM 64.0 TO 25.1 FT. BGS. 7:30 12/15/90 POURED 40 BAGS OF SACRETE FROM 25.1 TO SURFACE AND SET 6 1/2" STEEL FLUSHMOUNT COVER.

WELL DEVELOPMENT NOTES

SEE ATTACHED WELL DEVELOPMENT RECORD

WELL DEVELOPMENT FIELD RECORD

JOB NAME RCI/CSX Inv/TRI JOB NO. 903-3174.2 WELL NO. P-4

DEVELOPED BY JMF DATE OF INSTALL 12/12/90 SHEET 1 OF 1

STARTED DEVEL. 12-13-90 / 9:55 (DATE / TIME) COMPLETED DEVEL. 12/14/90 / 11 (DATE / TIME)

W.L. BEFORE DEVEL. 39.94 / 12/13/90 / 9:55 (DEPTH / DATE / TIME) AFTER DEVEL. / / (DEPTH / DATE / TIME)

WELL DEPTH: BEFORE DEVEL. 86.65 AFTER DEVEL. 86.65 WELL DIA. (in) 20

STANDING WATER COLUMN (FT.) 46.71 STANDING WELL VOLUME 12.65 gal.

SCREEN LENGTH 15.0 DRILLING WATER LOSS N/A gal.

DATE/TIME	VOLUME REMOVED (GALS)	FIELD PARAMETERS SPEC. COND. (umhos/cm)	TEMP. (C°)	pH (s.u.)	OTHER	REMARKS
12/13/90 9:55	10	740	10.1	6.13		Mod Turbid
12/13/90 10:30	23	820	12.2	6.84		|
12/13/90 11:30	38	760	11.0	7.01		↓
12/14/90 9:55	68	900	12.0	7.01		slightly turbid
	68	= TOTAL VOLUME REMOVED (gal.)				

DEVELOPMENT METHOD: Arch well pump

NOTES:

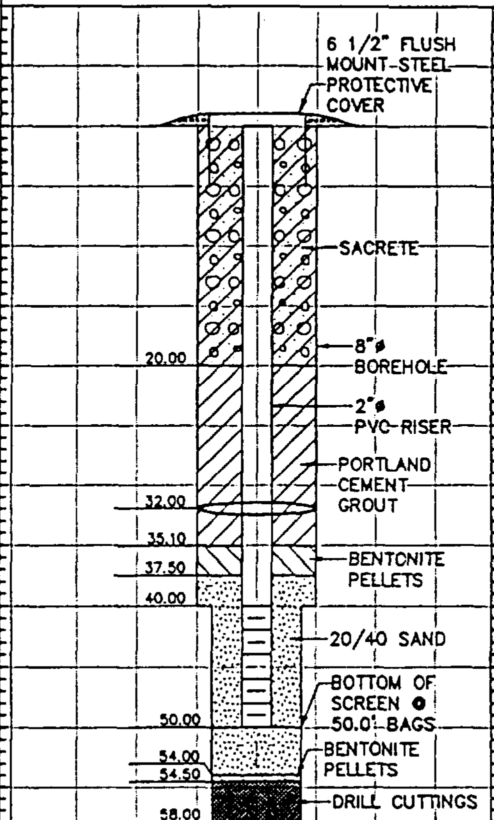
16

MONITORING WELL INSTALLATION LOG

JOB NO.	903-3174	PROJECT	RCI/CSX INV/TN	WELL NO.	P-5	SHEET	1 1
GA INSP.	JMF	DRILLING METHOD	AIR ROTARY	GROUND ELEV.	596.3	WATER DEPTH	N/A
WEATHER	RAIN	DRILLING COMPANY	MILLER DRILLING	COLLAR ELEV.	596.28	DATE/TIME	N/A
TEMP.	50°	DRILL RIG	SCHRAM T-450 DRILLER STEVE PRINCE	STARTED (TIME / DATE)	12:00 12/19/90	COMPLETED (TIME / DATE)	1:45 12/21/90
LOCATION / COORDINATES	N641456.4280,E1744623.6101						

MATERIALS INVENTORY

WELL CASING	2.0 in. dia. 40.0 l.f.	WELL SCREEN	2.0 in. dia. 10.0 l.f.	BENTONITE SEAL	3/8" PELLETS
CASING TYPE	FLUSH PVC	SCREEN TYPE	SLOTTED	INSTALLATION METHOD	POURED
JOINT TYPE	FLUSH SEAL	SLOT SIZE	(0.010)	FILTER PACK QTY.	4 BAGS
GROUT QUANTITY	8 BAGS / 56 BAGS	CENTRALIZERS	(1)	FILTER PACK TYPE	20/40 SAND
GROUT TYPE	PORTLAND / SACRETE	DRILLING MUD TYPE	N/A	INSTALLATION METHOD	TREMIED

ELEV./DEPTH	SOIL/ROCK DESCRIPTION	WELL SKETCH	INSTALLATION NOTES
	GROUND SURFACE		12:30 12/19/90 TAGGED BOTTOM AT 54.5 FT. BGS. (3.5 FT. DRILL CUTTINGS & GRAVEL). 1:00 POURED 1.5 BUCKETS OF BENTONITE PELLETS FROM 54.5 TO 54.0 TREMIED 1/2 BAG SAND FROM 54.0 TO 50.0 FT. BGS. SET 10.0 FT. OF SCREEN AND 40.0 FT. OF RISER AT 50.0 FT. BAGS TREMIED 3 1/2 BAGS OF 20/40 SAND FROM 50.0 TO 57.5 FT. BGS. POURED 3 5(GAL.) BUCKETS OF BENTONITE PELLETS FROM 37.5 TO 35.1 FT. BGS. 1:30 12/20/90 BEGAN GROUTING WITH 8 BAGS OF PORTLAND CEMENT 12/21/90 TAGGED CEMENT @ 20.0 FT. BGS. POURED 56 BAGS OF SACRETE FROM 20.0 FT. BGS. TO SURFACE. THE LARGE QUANTITY OF SACRETE IS DUE TO THE VOIDS IN THE FILL. SET 6 1/2" STEEL FLUSH MOUNT PROTECTIVE COVER.
0.0	"Fill Material" Firm brown SILT, little to some clay, and gray limestone ROCK FRAGMENTS, gravel, little fine sand.		
58.00	Hard, gray, "Bigby Cannon Limestone".		**WELL DEVELOPMENT NOTES** SEE ATTACHED WELL DEVELOPMENT RECORD

Boring Log

JOB NO.	903-3174	GA. INSP.	JMF	PROJECT	RCI/CSX INV/TN	BORING NO.	P-2
DEPTH HOLE	65.0	DEPTH WL.	13.10	DRILLING METHOD	AIR ROTARY/AIR HAMMER	SHEET	2 OF 2
TEMP	50°	TIME WL.	11:30 1/9/91	DRILLING COMPANY	MILLER DRILLING	SURFACE ELEV.	592.3
WEATHER	CLOUDY/RAIN	DRILL RIG	SCHRAM T-450	DRILLER	S. PRINCE	DATUM	MSL
COORDINATES	N 639800.8991 E 1745397.7713	WT. SAMPLER HAMMER	140 LB	DROP	30-INCHES	STARTED	3:15 1/5/91
LOCATION	CSX RADNOR RAILYARD	WT. CASING HAMMER		DROP		COMPLETED	2:55 1/9/91

ELEV. / DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
62.5 – 65.0	65.0'	HARD DARK BROWN TO DARK GREEN FOSSILIFEROUS COMPETENT HERMITAGE LIMESTONE	N/A	N/A	RC-1	ROCK CORE	RQD 95%	59/60	
		END OF BORING AT 65.0 FT. BGS							

JOB NO.	903-3174	CHECKED	JMF
SCALE	AS SHOWN	DATE DRAWN	2-4-91

Golder Associates

JOB NO. 903-3174	GA. INSP. JMF	PROJECT RCI/CSX INV/TN			BORING NO. P-3
DEPTH HOLE 95.0	DEPTH WL 82.03	DRILLING METHOD AIR ROTARY / AIR HAMMER			SHEET 1 OF 2
TEMP 55°	TIME WL 5:10 12/14/90	DRILLING COMPANY LAYNE ENVIRONMENTAL			SURFACE ELEV. 595.5
WEATHER CLEAR		DRILL RIG GUS PECH 1000R	DRILLER T. O'BRIAN		DATUM MSL
COORDINATES N 640609.4038 E 1744783.4466		WT. SAMPLER HAMMER 140	DROP 30-INCH		STARTED 10:30 12/12/90
LOCATION CSX RADNOR RAILYARD		WT. CASING HAMMER	DROP		COMPLETED 6:30 12/14/90

ELEV. DEPTH		DESCRIPTION	UNIFIED CLASS.	BLOWS/FOOT	SAMPLES NUMBER	TYPE	HAMMER BLOWS PER 6 IN.	REC./ATT	REMARKS
		'FILL MATERIAL'							
2.5		STIFF BROWN SILT AND FINE SAND, AND GRAY LIMESTONE BOULDERS, ROCK FRAGMENTS, AND GRAVEL, LITTLE CLAY.	N/A	50+	SA-1	DO	50+ FOR 4"	4/4	
5.0									NOTE: NO DIESEL OR OIL CONTAMINATION OF SOIL SAMPLES
7.5			N/A	35	SA-2	DO	34-17-18	15/18	
10.0									
12.5			N/A	49	SA-3	DO	4-23-26	14/18	
15.0									
17.5			N/A	22	SA-4	DO	11-10-12	16/18	
20.0									
22.5			N/A	57	SA-5	DO	9-29-27	14/18	
25.0									
27.5	27.5		N/A	42	SA-6	DO	13-20-22	16/18	
30.0		STIFF BROWN TO REDDISH BROWN SILT, TRACE CLAY, TRACE RIVER WASHED GRAVEL							
32.5	32.5		ML	28	SA-7	DO	10-12-16	18/18	
35.0		HARD GRAY TO LIGHT GRAY BIGBY CANNON LIMESTONE							
37.5									
40.0									
42.5									
45.0									
47.5									
50.0									
52.5									
55.0									
57.5									

JOB NO. 903-3174
SCALE AS SHOWN

Golder Associates

CHECKED JMF
DATE DRAWN 2-4-91

MONITORING WELL INSTALLATION LOG

JOB NO. 903-3174 PROJECT RCI/CSX INV/TN WELL NO. P-6 SHEET 1 1

GA INSP. JMF DRILLING METHOD AIR ROTARY GROUND ELEV. 592.3 WATER DEPTH 11.86

WEATHER CLDY DRILLING COMPANY MILLER DRILLING COLLAR ELEV. 592.40 DATE/TIME 1/10/91 11:00

TEMP. 45° DRILL RIG SCHRAM T-450 DRILLER STEVE PRINCE STARTED 8:45 1/5/91 (TIME / DATE) COMPLETED 4:00 1/5/91 (TIME / DATE)

LOCATION / COORDINATES N639794.5572,E1745398.0071

MATERIALS INVENTORY

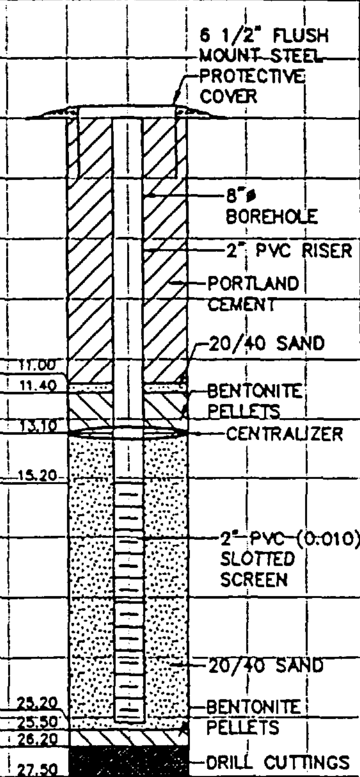
WELL CASING 2.0 in. dia. 15.5 l.f. WELL SCREEN 2.0 in. dia. 10 l.f. BENTONITE SEAL 3/8" PELLETS

CASING TYPE PVC SCREEN TYPE SLOTTED PVC INSTALLATION METHOD POURED

JOINT TYPE FLUSH JOINT SLOT SIZE (0.010) FILTER PACK QTY. 3 BAGS

GROUT QUANTITY 30 GAL. / 5 1/2 BAGS CENTRALIZERS (1) FILTER PACK TYPE 20/40 SAND

GROUT TYPE PORTLAND / SACRETE DRILLING MUD TYPE N/A INSTALLATION METHOD POURED

ELEV./DEPTH	SOIL/ROCK DESCRIPTION	WELL SKETCH	INSTALLATION NOTES
	GROUND SURFACE		8:20 1/5/91 TAGGED BOTTOM OF HOLE AT 26.2 FT. BGS POURED 1/2 GAL. OF BENTONITE PELLETS FROM 26.7 TO 25.5. POURED 1/4 GAL. OF 20/40 SAND FROM 25.5 TO 25.2. SET 10.0 FT. OF 0.010 SCREEN AND 15.5 FT. OF RISER. POURED 2 3/4 BAGS (20 GAL.) OF SAND FROM 25.2 TO 13.1 FT. BGS. 9:45 POURED (1) 5 GAL. BUCKET OF 3/8" BENTONITE PELLETS FROM 13.1 TO 11.4 FT. BGS. POURED 1/4 GAL. OF 20/40 SAND FROM 11.4 TO 11.0 FT. BGS. PUMPED 30 GAL. OF PORTLAND TYPE 1 CEMENT FROM 11.0 TO 0.5 FT. BGS. 3:30 P.M. POURED 5 1/2 BAGS OF SACRETE TO FORM PAD AND SET 6 1/2" FLUSH MOUNT STEEL COVER.
0.0 – 6.00	"Fill Material" Hard gray limestone boulders, rock fragments and gravel, little brown to tan SILT, little clay.		
6.00 – 27.50	Firm to stiff orange brown to tan SILT, little to and clay, trace river washed gravel.		
27.50	Hard gray, fine grained "Bigby Limestone".		**WELL DEVELOPMENT NOTES** SEE ATTACHED WELL DEVELOPMENT RECORD

2 4 0296

WELL DEVELOPMENT FIELD RECORD

JOB NAME RCI/CSX Inv/TN JOB NO. 903-3174.2 WELL NO. P-6

DEVELOPED BY JMF DATE OF INSTALL 1/5/91 SHEET 1 OF 1

STARTED DEVEL. 1/18/91 / 8:25 (DATE / TIME) COMPLETED DEVEL. 1/18/91 / 10:45 (DATE / TIME)

W.L. BEFORE DEVEL. 14.10 / 1/18/91 / 8:25 (DEPTH / DATE / TIME) AFTER DEVEL. 14.75 / 1/18/91 / 12:16 (DEPTH / DATE / TIME)

WELL DEPTH: BEFORE DEVEL. 25.2 AFTER DEVEL. 25.2 WELL DIA. (in) 2.0

STANDING WATER COLUMN (FT.) 11.10 STANDING WELL VOLUME 7.0 gal.

SCREEN LENGTH 10.0 DRILLING WATER LOSS N/A gal.

DATE/TIME	VOLUME REMOVED (GALS)	FIELD PARAMETERS SPEC. COND. (umhos/cm)	TEMP. (C°)	pH (s.u.)	OTHER	REMARKS
1/18/91 8:25	20	300	12.6	7.06		slightly turbid
1/18/91 9:30	40	310	12.4	7.10		
1/18/91 10:45	60	305	12.6	7.09		
	60	= TOTAL VOLUME REMOVED (gal.)				

DEVELOPMENT METHOD: Arch well pump

NOTES:

Golder Associates Inc.

WELL DEVELOPMENT FIELD RECORD

JOB NAME RC/BSX Inv/TN JOB NO. 903-3174.2 WELL NO. CSX-1

DEVELOPED BY MED DATE OF INSTALL N/A SHEET 1 OF 1

STARTED DEVEL. 12-14-90 / 11:30 (DATE / TIME) COMPLETED DEVEL. 12-14-90 / 12:45 (DATE / TIME)

W.L. BEFORE DEVEL. 23.69 / 12-14-90 / 11:30 (DEPTH / DATE / TIME) AFTER DEVEL. 23.69 / 12-14-90 / 12:45 (DEPTH / DATE / TIME)

WELL DEPTH: BEFORE DEVEL. 24.9 AFTER DEVEL. 24.9 WELL DIA. (in) 2.0

STANDING WATER COLUMN (FT.) 1.21 STANDING WELL VOLUME 1.0 gal.

SCREEN LENGTH 10.0 DRILLING WATER LOSS NONE gal.

DATE/TIME	VOLUME REMOVED (GALS)	FIELD PARAMETERS SPEC. COND. (umhos/cm)	TEMP. (C°)	pH (s.u.)	OTHER	REMARKS
12-14-90 12:00	0.5	850	10.1	6.56		Mod Turbid
12-14-90 12:30	32	900	10.5	6.31		Mod. Turbid
						(sulfur smell)
	32	= TOTAL VOLUME REMOVED (gal.)				

DEVELOPMENT METHOD: Manual bailing

NOTES:

2 4 0223

APPENDIX E

INTERIM MONITORING PROGRAM RESULTS

RESOURCE CONSULTANTS

CSX Transportation Co.
500 Water Street—SCJ350
Jacksonville, FL 32202

27–Aug–90
RCI Project No. 8–3553.04

TABLE 1A

ANALYTICAL REPORT

Samples collected on 7/11/90 at CSX–Radnor Yards, Nashville, TN
RCI Received 7/12/90

Sample Description	Brown's Creek Upstream from Yard	Roundhouse Area Storm Sewer	Classification Yard Area Storm Sewer	TOFC Yard Storm Sewer	Brown's Creek Downstream from Yard
RCI Sample Nos.	112035–39	112045–49	112051–55	112057–61	112040–44
Time Collected	1415	1230	1230	1230	1115
BOD, 5–day, 20°C	360	9	4	140	42
Boron	0.15	0.13	0.27	0.12	0.15
COD	1,860	19	31	765	217
MBAS	0.55	0.02	0.04	0.23	<0.02
Field pH (pH units)	7.0	7.2	7.5	7.44	7.2
Lab pH (pH units)	6.3	7.0	7.3	6.8	6.9
Phenols	<0.01	0.03	<0.01	0.01	<0.01
Suspended Solids	119	<1	<1	48	14
Petroleum/Mineral Oil and Grease	<2	<2	<2	<2	<2
TRPH*	16	<0.5	<0.5	1.1	<0.5
Field Temp, °C	32.5	16.0	14.0	28.7	20.0

All units are mg/l unless otherwise noted.
*Total Recoverable Petroleum Hydrocarbons by California GC Method.

NOTES: Milky color in Browns Creek upstream from yard, and higher than normal temperatures. Color and high temperatures also apparent in TOFC storm sewer samples (because of upstream flow included) and at Browns Creek downstream sampling point.

RESOURCE CONSULTANTS

CSX Transportation Co.
500 Water Street—SCJ350
Jacksonville, FL 32202

27-Aug-90
RCI Project No. 8-3553.04

TABLE 1B

ANALYTICAL REPORT

Groundwater samples collected on 7/11/90 at CSX-Radnor Yards, Nashville, TN
RCI Received 7/12/90

Sample Description	Diesel Storage Tank Area Well	Lube Oil Storage/ Pump Area Well
RCI Sample Nos.	112062-65	112066
Well Depth (ft.)	51.55	27.25
Water Level (ft.)	13.30	24.20
Water Depth (ft.)	38.25	3.05
Well Dia. (in.)	4	2
Volume of Water (gal.)	25	0.5
Volume to Purge (gal.)	75	1.5
Gal. Actually Purged	74.3	2.0
Date Purged	7/11/90	7/11/90
Time Purged	1600	1700
Date Sampled	7/12/90	7/12/90
Time Sampled	1500	1530
Field pH (pH units)	6.9	6.6
Field Temp. (°C)	18.5	21.5
Turbidity (NTU)	100	120
Boron	0.37	0.29
Cadmium	<0.005	<0.005
Chromium	<0.02	0.07
Copper	<0.01	0.39
Nickel	<0.02	0.15
Lead	0.004	0.40
Zinc	0.04	0.40
PCBs	<0.001	<0.001
Benzene, Toluene, Xylene	<0.005	<0.005
Petroleum/Mineral Oil and Grease	<2	<2
TRPH*	<0.5	1.2

All units are mg/l unless otherwise noted.
*Total Recoverable Petroleum Hydrocarbons by California GC Method.

RESOURCE
CONSULTANTS

2 4 0301

CSX Transportation Co.
500 Water Street—SCJ350
Jacksonville, FL 32202

27-Aug-90
RCI Project No. 8-3553.04

TABLE 1C

ANALYTICAL REPORT

Sediment samples collected** on 7/11/90 at CSX-Radnor Yards, Nashville, TN
RCI Received 7/12/90

Sample Description	Roundhouse Area Storm Sewer Sediment	Classification Yard Area Storm Sewer Sediment
RCI Sample Nos.	112050	112056/113729
Time Collected	1230	1230
Petroleum/Mineral Oil and Grease	1,220	1,400
TRPH*	2,000 (mg/kg)	270 (mg/kg)

All units are mg/l unless otherwise noted.
*Total Recoverable Petroleum Hydrocarbons by California GC Method.
**Samples were collected from floor (invert) of storm sewers about two to three feet upstream from junction manhole.

RESOURCE CONSULTANTS

CSX Transportation Co.
500 Water Street—SCJ350
Jacksonville, FL 32202

22–Oct–90
RCI Project No. 8–3553.04

TABLE 2A

ANALYTICAL REPORT

Surface water samples collected on 8/16/90 at CSX–Radnor Yards, Nashville, TN
RCI Received 8/16/90

Sample Description	Brown's Creek Upstream from Yard	Roundhouse Area Storm Sewer	Classification Yard Area Storm Sewer	TOFC Yard Storm Sewer	Brown's Creek Downstream from Yard
RCI Sample Nos.	113546–49	113554–57	113558–61	113562–65	113550–53
Time Collected	1430	1230	1300	1330	1130
BOD, 5–day, 20°C	3	2	2	2	2
Boron	0.44	0.27	0.53	0.42	0.58
COD	8	11	<5	10	<5
MBAS	0.02	<0.02	<0.02	0.02	<0.02
Field pH (pH units)	7.8	7.1	7.4	7.8	8.0
Lab pH (pH units)	7.2	7.4	7.7	8.1	7.7
Phenols	<0.01	<0.01	<0.01	<0.01	<0.01
Suspended Solids	4	3	<1	5	2
Total Organic Carbon	<3	<3	<3	<3	<3
Petroleum/Mineral Oil and Grease	<2	<2	<2	<2	<2
TRPH*	<0.5	0.7	<0.5	<0.5	<0.5
Field Temp, °C	28.6	17.7	15.6	21.4	27.7

All units are mg/l unless otherwise noted.
*Total Recoverable Petroleum Hydrocarbons by California GC Method.

NOTES: ______________________________

RESOURCE
CONSULTANTS

CSX Transportation Co.
500 Water Street—SCJ350
Jacksonville, FL 32202

22-Oct-90
RCI Project No. 8-3553.04

TABLE 2B

ANALYTICAL REPORT

Groundwater samples collected on 8/17/90 at CSX-Radnor Yards, Nashville, TN
RCI Received 8/17/90

Sample Description	Diesel Storage Tank Area Well	Lube Oil Storage/ Pump Area Well
RCI Sample Nos.	113,574-78	113,579-83
Well Depth (ft.)	51.55	27.25
Water Level (ft.)	13.0	23.70
Water Depth (ft.)	38.55	3.55
Well Dia. (in.)	4	2
Volume of Water (gal.)	25.2	0.6
Volume to Purge (gal.)	75.6	1.8
Gal. Actually Purged	76	8
Date Purged	8/16/90	8/16/90
Time Purged	1400	1415
Date Sampled	8/17/90	8/17/90
Time Sampled	1330	1400
Field pH (pH units)	7.0	6.6
Field Temp. (°C)	22.1	21.8
Turbidity	>200	>200
Boron	0.84	0.65
Cadmium	<0.005	<0.005
Chromium	<0.02	0.07
Copper	<0.02	0.28
Nickel	<0.02	0.10
Lead	0.009	0.26
Zinc	0.06	0.36
PCBs	<0.002	<0.002
Benzene, Toluene, Xylene	<0.005	<0.005
TRPH*	<0.5	0.8

All units are mg/l unless otherwise noted.
*Total Recoverable Petroleum Hydrocarbons by California GC Method.

RESOURCE CONSULTANTS

CSX Transportation Co.
500 Water Street—SCJ350
Jacksonville, FL 32202

22-Oct-90
RCI Project No. 8-3553.04

TABLE 3A

ANALYTICAL REPORT

Surface water samples collected on 9/24/90 at CSX-Radnor Yards, Nashville, TN
RCI Received 9/24/90

Sample Description	Brown's Creek Upstream from Yard	Roundhouse Area Storm Sewer	Classification Yard Area Storm Sewer	TOFC Yard Storm Sewer	Brown's Creek Downstream from Yard
RCI Sample Nos.	115086-89	115094-97	115098-101	115102-65	115090-93
Time Collected	1150	1100	1110	1120	1130
BOD, 5-day, 20°C	<2	2	2	2	2
Boron	0.32	0.58	0.71	0.24	0.66
COD	<20	<20	<20	<20	<20
MBAS	0.23	0.02	0.03	0.04	0.02
Field pH (pH units)	7.8	7.1	7.4	7.8	8.0
Lab pH (pH units)	8.4	8.2	8.2	8.3	8.3
Phenols	<0.01	<0.01	<0.01	<0.01	<0.01
Suspended Solids	3	<1	1	4	<1
Total Organic Carbon	<3	3.6	<3	3.6	<3
TRPH*	<0.5	<0.5	<0.5	<0.5	<0.5
Field Temp, °C	20.0	17.7	16.5	18.8	17.4

All units are mg/l unless otherwise noted.
*Total Recoverable Petroleum Hydrocarbons by California GC Method.

NOTES: ______

(RCI Sample Nos. are 115,0xx Series)

RESOURCE CONSULTANTS

CSX Transportation Co.
500 Water Street—SCJ350
Jacksonville, FL 32202

22-Oct-90
RCI Project No. 8-3553.04

TABLE 3B

ANALYTICAL REPORT

Groundwater samples collected on 9/25/90 at CSX-Radnor Yards, Nashville, TN
RCI Received 9/25/90

Sample Description	Diesel Storage Tank Area Well	Lube Oil Storage/ Pump Area Well
RCI Sample Nos.	115129-33	115124-28
Well Depth (ft.)	51.6	27.3
Water Level (ft.)	13.2	23.9
Water Depth (ft.)	38.4	3.4
Well Dia. (in.)	4	2
Volume of Water (gal.)	25.0	10.6
Volume to Purge (gal.)	75.0	1.8
Gal. Actually Purged	75	8
Date Purged	9/24/90	9/24/90
Time Purged	1315	1325
Date Sampled	9/25/90	9/25/90
Time Sampled	1030	1000
Field pH (pH units)	7.0	6.5
Field Temp. (°C)	21.7	22.0
Turbidity	--	--
Boron	0.66	0.52
Cadmium	<0.005	<0.005
Chromium	<0.02	0.17
Copper	<0.01	0.61
Nickel	<0.02	0.26
Lead	0.19	1.0
Zinc	0.03	0.59
PCBs	0.002	<0.001
Benzene, Toluene, Xylene	<0.005	<0.005
TRPH*	0.89	5.5

All units are mg/l unless otherwise noted.
*Total Recoverable Petroleum Hydrocarbons by California GC Method.

RESOURCE
CONSULTANTS

CSX Transportation Co.
500 Water Street—SCJ350
Jacksonville, FL 32202

6–Dec–90
RCI Project No. 8–3553.04

TABLE 4A

ANALYTICAL REPORT

Surface water samples collected on 10/29/90 at CSX–Radnor Yards, Nashville, TN
RCI Received 10/29/90

Sample Description	Brown's Creek Upstream from Yard	Roundhouse Area Storm Sewer	Classification Yard Area Storm Sewer	TOFC Yard Storm Sewer	Brown's Creek Downstream from Yard
RCI Sample Nos.	116817-19; 832-34	11829-31; 844-846	116,826-28; 841-843	116823-25; 838-840	116820-22; 835-837
Time Collected	1230	1155	1210	1215	1030
BOD, 5–day, 20°C	<2	<2	<2	<2	<2
Boron	0.17	0.50	6.7	0.07	0.14
COD	9	9	3	6	7
MBAS	0.04	0.26	<0.02	0.19	<0.02
Field pH (pH units)	7.6	7.2	7.5	7.6	7.5
Lab pH (pH units)	8.0	7.7	7.6	7.9	7.8
Phenols	<0.005	<0.005	<0.005	<0.005	<0.005
Suspended Solids	3	<1	<1	3	<1
Total Organic Carbon	4	4	<3	<3	<3
TRPH*—GC Method**	<0.5	<0.5	<0.5	<0.5	<0.5
—IR Method	5	<1	2	3	7
—Gravimetric	3	<2	<2	2	<2
Field Temp, °C	17.7	17.7	17.1	17.7	14.2

All units are mg/l unless otherwise noted.
*Total Recoverable Petroleum Hydrocarbons
**California GC Method.

NOTES:

APPENDIX F

TRPH ANALYSIS

RESOURCE CONSULTANTS

BOREHOLE 1

LOCATION: Wastewater Treatment Area, NW of Diesel Tank
ELEVATION: 582.0 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–3.0	2.0	580.0	390	
	6.0–8.0	7.0	575.0	18,700	79.3%
	11.0–13.0	12.0	570.0	1,700	
	13.0–15.0	14.0	568.0	750	
Groundwater	–	7.9	574.1	40	29,000

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE 2

LOCATION: Northwest of Roundhouse
ELEVATION: 601.0 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–3.0	2.00	599.0	46,900	
	14.0–15.5	14.75	586.3	1,030	76.6%
	117.0–18.5	17.75	583.3	460	
	22.0–23.5	22.75	578.3	1,030	
Groundwater	–	24.10	576.9	61	14,200

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE 3

LOCATION: East of Lube Oil Storage Area
ELEVATION: 604.0 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–3.0	2.00	602.0	840	
	24.0–26.0	25.00	579.0	840	81.9%
	28.0–30.0	29.00	575.0	420	
Groundwater	–	22.90	581.1	73	NA

Note 1: All units are in ppm unless otherwise indicated.
NA = Not Analyzed.

BOREHOLE 3A

LOCATION: East of Lube Oil Storage Area
ELEVATION: 600.0 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	9.0–10.0	9.50	590.5	15,000	
	10.0–12.0	11.00	589.0	8,400	
	16.0–18.0	17.00	583.0	12,000	81%
	21.0–23.0	22.00	578.0	<20	
	26.0–28.0	27.00	573.0	<20	
Groundwater	–	22.90	581.1	30	6,100

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE 4

LOCATION: East of Diesel Shop
ELEVATION: 595.0 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–3.0	2.00	593.0	1,500	
	6.0–8.0	7.00	588.0	1,750	
	11.0–13.0	12.00	583.0	975	
	16.0–18.0	17.00	578.0	1,245	79.8%
	21.0–23.0	22.00	573.0	1,550	
	26.0–27.0	26.50	568.5	<20	
	29.6–31.6	30.60	564.4	120	
Groundwater	–	21.30	573.7	410	1,000

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE 5

LOCATION: Inside Circle of Roundhouse
ELEVATION: 600.7 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	2.0–4.0	3.00	597.7	3,600	
	7.0–9.0	8.00	596.0	<20	
	16.0–18.0	17.00	587.0	<20	
	23.2–25.2	24.20	579.8	130	82%
Groundwater	–	19.30	584.7	750	19.7%

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE 5A

LOCATION: Inside Circle of Roundhouse
ELEVATION: 600.6 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Groundwater	–	–	Note 2	0.2	26%

Note 1: All units are in ppm unless otherwise indicated.
Note 2: Groundwater sample was from bedrock.

BOREHOLE LBH-1

LOCATION: Proposed Lube Oil Storage Area
ELEVATION: 598.6 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–3.0	2.00	596.6	150	
	3.0–5.0	4.00	594.6	<20	
	5.0–7.0	6.00	592.6	<20	
	7.0–9.0	8.00	590.6	60	
	9.0–11.0	10.00	588.6	<20	
Groundwater	–	22.20	576.4	<0.1	128,000

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE LBH-2

LOCATION: Proposed Lube Oil Storage Area
ELEVATION: 598.6 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–3.0	2.00	596.6	1,020	
	3.0–5.0	4.00	594.6	<20	
	15.0–17.0	16.00	582.6	<20	

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE 6

LOCATION: South Berm of Diesel Storage Tank Containment Area
ELEVATION: 586.2 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	4.0–6.0	5.00	581.2	460	
	14.0–16.0	15.00	571.2	5,500	
	19.0–21.0	20.00	566.2	5,500	84.2
	24.0–26.0	25.00	561.2	240	
	29.0–31.0	30.00	556.2	<20	
Groundwater	–	14.10	572.1	410	226

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE DT-1 AND DT-1A

LOCATION: Adjacent to Diesel Storage Tank
ELEVATION: 582.5 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils: DT-1	1.0–3.0	2.00	580.5	280	
	6.0–8.0	7.00	575.5	2,050	
	11.0–13.0	12.00	570.5	46,200	
	16.0–18.0	17.00	565.5	760	
	21.0–23.0	22.00	560.5	230	
Soils: DT-1A	9.0–11.0	10.00	572.5	670	
Groundwater	–	11.00	571.5	80	548

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE 8

LOCATION: South of Car Shop
ELEVATION: 598.2 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	5.0–7.0	6.00	592.2	5,000	
	10.0–12.0	11.00	587.2	<20	
	15.0–17.0	16.00	582.2	2,500	
	23.0–25.0	24.00	574.2	29,000	76.7%
	31.0–33.0	32.00	566.2	100	
	36.0–37.0	36.50	561.7	<20	
Groundwater	–	25.00	573.2	0.4	30,900

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE 9

LOCATION: East Side of Load Test Cell
ELEVATION: 600.7 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–3.0	2.00	598.7	40	
	6.0–8.0	7.00	593.7	<20	
	18.5–20.0	19.25	581.5	<20	
	21.5–23.0	22.25	578.5	20	
	23.0–24.5	23.75	577.0	120	
Groundwater	–	22.00	578.7	<0.1	122

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE 10

LOCATION: Oil Recovery Manhole/Lift Station
ELEVATION: 588.6 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	11.0–13.0	12.00	576.6	270	
	16.0–18.0	17.00	571.6	<20	
	27.0–27.8	27.40	561.2	<20	80.5%
Groundwater	–	–	Note 2	0.2	22

Note 1: All units are in ppm unless otherwise indicated.
Note 2: Groundwater sample from bedrock.

BOREHOLE 11

LOCATION: East of Classification Yard, 300 ft West of Storm Sewer Junction Manhole
ELEVATION: 595.0 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–2.5	1.75	593.3	<20	
	6.0–7.5	6.75	588.3	<20	
	18.0–19.5	18.75	576.3	<20	
	26.0–27.5	26.75	568.3	<20	83.5%
	31.0–32.5	31.75	563.3	<20	
	38.0–39.5	38.75	556.3	<20	
	43.0–44.5	43.75	551.3	<20	
	48.0–49.5	48.75	546.3		
Groundwater	–	23.70	571.3	<0.1	1,530

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE 12

LOCATION: Northwest of Humptrack
ELEVATION: 596.5 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Groundwater	–	36.80	558.2	<0.1	610

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE 13

LOCATION: West Side of Oil Collection Manhole, West of Humptrack
ELEVATION: 598.5 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–2.5	1.75	596.8	<20	
Groundwater	–	4.30	594.2	3,270	2,420

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE P1

LOCATION: Northeast Corner of Car Shop Area
ELEVATION: 600.2 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–3.0	2.00	598.2	<20	
	7.0–8.5	7.75	592.5	<20	
	12.0–13.5	12.75	587.5	<20	
	24.5–26.0	25.25	575.0	<20	84.3%
	29.0–30.5	29.75	570.5	<20	
Groundwater	–	25.40	574.8	<0.1	12,900

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE P2

LOCATION: Southeast Corner of Classification Yard
ELEVATION: 592.2 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	6.0–8.0	7.00	585.2	50	
	15.0–17.0	16.00	576.2	<20	
	21.0–23.0	22.00	570.2	<20	
	27.5–27.5	27.50	564.7	150	80.5%
Groundwater	–	–	Note 2	0.3	112

Note 1: All units are in ppm unless otherwise indicated.
Note 2: Groundwater sample was from bedrock.

BOREHOLE P3

LOCATION: TOFC Yard Area
ELEVATION: 595.5 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–2.5	1.75	593.8	<20	
	6.0–7.5	6.75	588.8	80	
	11.0–12.5	11.75	583.8	50	
	16.0–17.5	16.75	578.8	<20	
	21.0–22.5	21.75	573.8	350	
	26.0–27.5	26.75	568.8	<20	
	31.0–32.5	31.75	563.8	<20	
Groundwater	–	–	–	1.1	11,200

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE P4

LOCATION: Junction Storm Sewer Manhole
ELEVATION: 596.6 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Soils	1.0–2.5	1.75	594.9	<20	
	6.0–7.5	6.75	589.9	20	
	11.0–12.5	11.75	584.9	80	
	17.0–18.5	17.75	578.9	<20	
	22.0–23.5	22.75	573.9	<20	
	27.0–28.5	27.75	568.9	<20	
	42.0–43.5	42.75	553.9	110	
	47.0–48.5	47.75	548.9	3,000	79.9%
	54.0–56.5	55.25	541.4	<20	
Groundwater	–	40.14	556.5	<0.1	6

Note 1: All units are in ppm unless otherwise indicated.

BOREHOLE P6

LOCATION: Southeast Corner of Classification Yard
ELEVATION: 592.4 ft

	Sample Interval (ft)	Average Depth (ft)	Sample Elevation (ft)	TRPH	Total Solids
Groundwater	–	17.0	575.4	<0.1	3,140

Note 1: All units are in ppm unless otherwise indicated.